Joint CSCE Construction Specialty & CRC Conference 2025
Conférence conjointe spécialisée en construction de la SCGC et CRC-2025

Montreal, Quebec
July 28-31, 2025 / *28-31 juillet 2025*

Decision-Support tool for Selecting the Best Delivery Method in Sustainable Construction Projects

Nima Moghimi[1]*, Mahsa Honari Kalateh[1], Ahmed Mohamed[1], Deyaaldeen Alnakdali[1], Mohamad Itani[1], Julie Munoz[1], Ahmed Hammad[2], Farook Hamzeh[3]

[1]Graduate Student, Department of Civil and Environmental Engineering, University of Alberta, Canada
[2]Associate Professor, Department of Civil and Environmental Engineering, University of Alberta, Canada
[3]Professor, Department of Civil and Environmental Engineering, University of Alberta, Canada

*Corresponding Author: nmoghimi@ualberta.ca

ABSTRACT: The construction industry's high resource consumption and greenhouse gas emissions emphasize the need for sustainable approaches. Sustainable construction minimizes environmental impact while balancing environmental, social, and economic priorities to promote long-term sustainability. A critical factor in achieving sustainable construction is the selection of an appropriate project delivery method (PDM). This study introduces a decision-support system (DSS) to guide the selection of the most suitable PDM for sustainable construction projects. Initially, a set of twelve key criteria for sustainable PDM selection is identified through an extensive literature review and expert consultations. These criteria are then weighted by importance based on survey responses from industry professionals specializing in sustainable construction. To evaluate the performance of four common PDMs (i.e., design–bid–build (DBB), design–build (DB), construction management at risk (CMR), and integrated project delivery (IPD)), the experts were asked to assess each method's effectiveness against the selected criteria. Using the VIKOR method, a DSS application is developed to rank these PDM options according to the collected data. The developed DSS incorporates user preferences to generate tailored recommendations aligned with specific project needs and sustainability objectives. The proposed DSS is validated through application to two real-project case studies, wherein stakeholders provide input on criterion weighting relevant to their respective projects. Findings indicate that the application offers valuable insights for PDM selection in sustainable construction, enhancing decision-making and aligning project delivery with sustainability goals.
Key Words: Sustainable Construction, Project Delivery Methods (PDM), Decision-Making Framework, VIKOR Method, Stakeholder Preferences, Sustainability Criteria

1. INTRODUCTION

The construction industry has recently experienced significant global growth—Italy's sector, for example, grew by 23% in 2021, with France, Canada, and the United States also reporting increases (Programme, 2022). However, construction contributes roughly 37% of global CO_2 emissions (Programme, 2022), while in Canada it accounts for about 35% of GHG emissions and 50% of natural resource consumption (Ruparathna & Hewage, 2015b). These figures underscore the urgent need to prioritize sustainability in construction. Integrating sustainable practices can reduce environmental impact, lower long-term costs, and improve resource efficiency (Švajlenka et al., 2018; Shahrokhishahraki et al. 2024a) . Despite these benefits, challenges such as high initial costs, complex implementation, and coordination issues remain, as sustainable practices often require the use of specialized materials, advanced technologies, and additional planning efforts—factors that can increase upfront investment compared to conventional construction methods (Ruparathna & Hewage, 2015a). A critical factor in overcoming these challenges is the selection of an appropriate Project Delivery Method (PDM) (Zhong et al., 2022), which defines the roles and relationships among key stakeholders (Ahmed & El-Sayegh, 2021) and can significantly affect a project's sustainability outcomes.

While many studies have examined PDMs in traditional projects and offered decision-support tools (Ahmed et al., 2024; Zhong et al., 2022), there is a notable gap in tools tailored to sustainable construction. This research addresses that gap by developing objective, sustainability-focused criteria for evaluating PDMs. It begins with a literature review and expert consultations to refine these criteria, followed by surveys that assess the importance of each criterion and the effectiveness of four common PDMs: Design-Bid-Build, Design-Build, Construction Manager at Risk, and Integrated Project Delivery. Using the collected data, a decision-making framework based on the VIKOR method is built; the method is chosen because a single, compromise-based ranking is produced with only one intuitively set parameter, while overall utility loss and worst-criterion regret are jointly minimised—advantages that avoid the incomparability zones and extensive threshold tuning required by alternative outranking tools such as ELECTRE or PROMETHEE.

2. LITRATURE REVIEW

2.1 Major Delivery Methods

Selecting the right PDM is critical for achieving project objectives, as each method affects timelines, costs, risk distribution, and stakeholder coordination differently (Ahmed & El-Sayegh, 2020). The most common PDMs are Design-Bid-Build (DBB), Design-Build (DB), Construction Manager at Risk (CMAR), and Integrated Project Delivery (IPD) (Engebø et al., 2020). DBB is the traditional approach, where a completed design initiates bidding and subsequent construction. Despite its simplicity, it often suffers from poor coordination between design and construction teams, increasing risks and delays (Ahmed & El-Sayegh, 2021). DB integrates design and construction under one contract, speeding up delivery and reducing owner risk, though it may lessen owner control over the final product (Zhong et al., 2022). CMAR allows early contractor involvement to improve cost certainty but involves a complex selection process for the construction manager (Zhong et al., 2022). IPD unites the owner, designer, and contractor under a single contract to foster trust and shared risk; however, it demands a high level of collaboration, which can be challenging in complex projects (Agbaxode et al., 2024; He et al., 2024).

2.2 Selection of Delivery Methods

The choice of PDM has evolved from traditional DBB to more collaborative models like IPD, yet the optimal method depends on specific project needs. Studies indicate that similar projects may benefit from different methods—for example, DB and CMAR have been found effective for highway projects (Alleman et al., 2017; Demetracopoulou et al., 2020). As projects become more complex, selection criteria must expand beyond traditional factors—such as cost, time, scope, and stakeholder capabilities (Antoine et al., 2019; Martin et al., 2016; Zhang et al., 2020)—to include sustainability aspects like integration, green liabilities, team dynamics, and innovation (Ahmed & El-Sayegh, 2024; Brahmi et al., 2022; Gunhan, 2019; Larsson et al., 2022; Robichaud & Anantatmula, 2011; Silvius & Schipper, 2014; Swarup et al., 2011). Advanced selection methods—such as the Analytic Hierarchy Process (AHP), fuzzy logic, and multi-attribute decision support tools—help balance these criteria and reduce subjectivity (Al Khalil, 2002; Alleman et al., 2017; An et al., 2018; Boran, 2011; Chen et al., 2011; Demetracopoulou et al., 2020; Feghaly et al., 2020; Khwaja et al., 2018; Li et al., 2015; Li et al., 2019; Mostafavi & Karamouz, 2010; Nguyen et al., 2020; Noorzai, 2020; Qiang et al., 2015; Xia et al., 2011; Zhu et al., 2020). Despite these advances, existing frameworks often fail to fully integrate traditional metrics—such as cost, schedule adherence, and scope control—with broader sustainability criteria like stakeholder engagement, environmental certifications, and contractual flexibility. For instance, many decision-support tools focus heavily on minimizing project duration or maximizing budget efficiency, without adequately considering long-term environmental performance or social equity outcomes (Shahrokhishahraki et al. 2024b). To address this gap, this study proposes the VIKOR method—a compromise-based, multi-criteria decision tool that ranks alternatives by their proximity to an ideal solution while balancing group utility and individual regret. Unlike AHP or TOPSIS, VIKOR simplifies the decision-making process with adjustable criteria weights, making it particularly suitable for complex, sustainability-focused projects.

3. METHODOLOGY

The methodology of this study consists of three main phases as shown in Figure 1. The first phase involves identifying the effective criteria for selecting the appropriate PDM for sustainable construction projects. In the second phase, data collection is conducted using two questionnaires. The first survey gathers data on the weight of each criterion toward sustainable construction projects, while the second survey assesses the effectiveness of the four major PDMs (i.e., DBB, DB, CMAR, and IPD) in fulfilling each identified criterion. The final phase is the development of a decision-support system that incorporates the collected data, allowing users to input their subjective preferences for each criterion. Using the VIKOR analysis model to rank PDMs alternatives. VIKOR results provides a prioritized list that reflects both expert insights—collected from professionals across the architecture, engineering, and construction (AEC) industry—and user preferences, which refer to project-specific inputs provided by end-users of the tool such as project owners, developers, or decision-makers involved in selecting the delivery method.

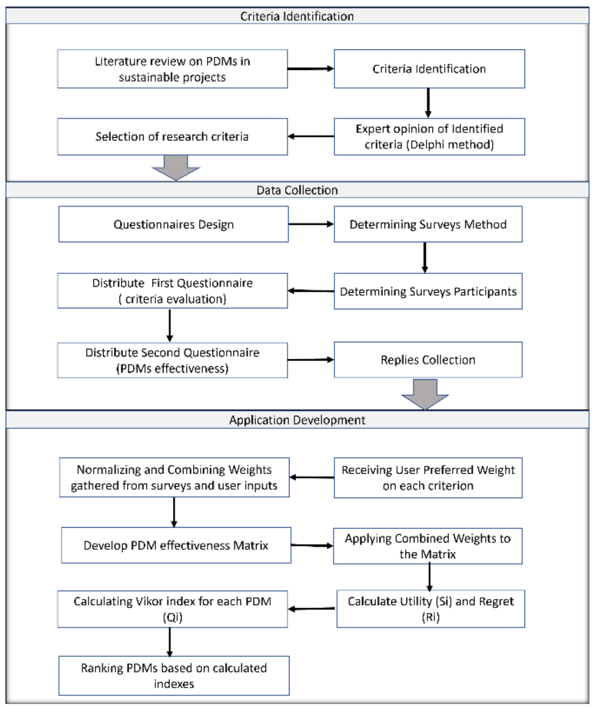

Figure 1: Structure of the Proposed Methodology

3.1 Criteria Identification

A comprehensive literature review was carried out, using the keywords "sustainability," "PDMs," "criteria," and "green buildings," and thirty-eight candidate factors influencing PDM selection in sustainable construction were initially extracted. Validation and refinement were subsequently undertaken through a two-round Delphi process involving 24 anonymized experts drawn in equal proportions from owner, designer, contractor, and sustainability-consultant groups. In each round, only summary statistics (median, inter-quartile range, and rating distributions) were returned to the panel by an independent research assistant who played no role in the analysis, thereby preventing any single investigator from steering the discussion. Iteration was halted once every criterion's inter-quartile range fell below 1 on the 1–9 importance scale, signalling consensus and ensuring that no dominant voice limited the scope of opinion. This protocol yielded a balanced, agreed-upon set of twelve criteria that capture the environmental, economic, and social dimensions of sustainable project delivery; these are presented in Table 1.

Table 1: Final List of Criteria

No	Criteria Name	Description
1	Manage budget and minimize risk	Complete projects on time and reduce delays.
2	Ensure timely project completion	Ensure timely procurement of materials and technology.
3	Facilitate procurement	Apply efficient and effective procurement system
4	Define project scope and adapt	Clearly define the project scope and allow for adaptability to changing requirements.
5	Manage complexity and coordination	Manage complexity, coordinate effectively across teams, and ensure confidentiality with project-specific knowledge.
6	Early construction involvement	Engage stakeholders early in decision-making, leveraging diverse expertise to improve decisions.
7	Foster teamwork and communication	Promote active client and stakeholder participation, teamwork, open communication, and conflict resolution through dialogue.
8	Achieve sustainability certifications	Assign responsibility for sustainability certifications and ensure compliance with green standards.
9	Set early sustainability benchmarks	Establish green benchmarks early to align with sustainability goals and project objectives.
10	Encourage innovation with rewards	Use performance-based rewards to drive innovation through contracts.
11	Structure flexible contracts	Design contracts to adapt to evolving project needs.
12	Align contracts with sustainability	Ensure contracts align with sustainable goals.

3.2 Data Collection

Two questionnaire surveys were designed and distributed among construction professionals from different backgrounds. The first questionnaire focused on weighing the various criteria and evaluating the relative importance of the identified key criteria. The second questionnaire focused on assessing the effectiveness of the four major PDMs (i.e., DBB, DB, CMAR, and IPD) in fulfilling each identified criterion. Both questionnaires employed a linguistic judgment scale, later converted into numerical values ranging from 1 to 9, as shown in Table 2. To account for varying levels of professional experience, a scaling system was applied to weight responses accordingly: participants with less than 5 years of experience were assigned a weight of 0.7, those with 5–10 years a weight of 0.85, and those with over 10 years a full weight of 1.0 (see Table 3). This tiered weighting approach was adopted to moderately differentiate expert input without overemphasizing seniority and follows conventions established in similar decision-support studies. To limit the inherent subjectivity of a survey-based framework, several safeguards were applied: (i) expert weights were normalised and experience-adjusted before use, (ii) internal consistency was verified (Cronbach's $\alpha = 0.81$) and items with low item-total correlations were discarded, (iii) a ±10 % one-at-a-time sensitivity analysis showed that the top-ranked PDM remained unchanged in 96 % of trials, and (iv) the final rankings were cross-validated against two real projects, one successful and one unsuccessful, to confirm practical plausibility.

Table 2: Linguistics scale for criteria comparison

Numeric value	Subjective description
1	Very low
3	Low
5	Medium
7	High
9	Very high

Table 3: Respondent weighting scale

Corresponding Weight	Years of experience
0.7	Less than 5 years
0.85	Between 5-10 years
1	More than 10 years

3.3 Data Collection

The development stage of the decision-making framework involves two main steps, detailed in the following subsections. The first step calculates the combined weights based on responses from questionnaire participants and user preference inputs. The second step applies the VIKOR method to rank the PDM alternatives according to their VIKOR index.

3.3.1 Criteria Weight Combination

Alongside expert input, user preferences for the criteria were gathered through a graphical user interface (GUI) integrated into the application. Through the GUI, users rated the importance of each criterion using the same verbal scale presented in Table 2. Both the criteria weights from experts and the user inputs were normalized to ensure that the combined weight of all criteria equaled 1. The normalized weight for each criterion was calculated as follows:
[1] $Normalize\ Critereon\ Weight_j = \ Critereon\ Weight_j \ / \sum_{i=1}^{n} Critereon\ Weight_i$

Next, user preferences were integrated with the expert-assigned weights for sustainability criteria to compute a combined weight W_i for each criterion: [2] $W_i = P_i \times I_i$

Where P_i represents the normalized user preference for criterion *i*, and I_i is the expert-assessed importance of criterion *i*. These combined weights were then applied to the effectiveness scores of each PDM, resulting in the weighted score for each PDM on each criterion: [3] $S_{ij} = W_i \times E_{ij}$

Where S_{ij} is the weighted score of PDM *j* on criterion *i*, and E_{ij} is the effectiveness of PDM *j* on criterion *i*.

3.3.2 Ranking of PDMs Alternatives Using VIKOR

The VIKOR method is a multicriteria ranking tool that finds a compromise solution by measuring each alternative's "closeness" to an ideal solution, even when initial preferences are unclear (Opricovic & Tzeng, 2004). It balances minimizing individual regret and maximizing group benefits, making it especially useful for decisions involving conflicting criteria (Ahmed et al., 2022; Opricovic & Tzeng, 2004; Taherdoost & Madanchian, 2023). In this analysis, VIKOR is applied to rank four PDMs (DBB, DB, CMAR, and IPD) through following structured steps:

1. **Define Alternatives:** Let alternatives be $x_1, x_2, ..., x_m$ with each criterion value f_{ij} for $j = 1, ..., m$ and $i = 1, ..., n$. x_j , the value of the *i*-th criterion is denoted by f_{ij}, where represents the *i*-th criterion function for alternative x_j. Here, *m* is the total number of alternatives, and *n* is the number of criteria.

2. **Determine Benchmarks:** For each criterion, identify the ideal solution $f_i^* = \max\{f_{ij}\}$ and the negative-ideal solution $f_i^- = \min\{f_{ij}\}$.

3. **Compute Utility and Regret Measures:** For each alternative: Utility: [4] $\mathrm{S_j} = \sum_{i=1}^{n} \mathrm{wi}\ \frac{(f_i^* - f_{ij})}{(f_i^* - f_i^-)}$,and Regret: [5] $\mathrm{R_j} = \max\{\mathrm{wi}\ \frac{(f_i^* - f_{ij})}{(f_i^* - f_i^-)}\}$
4. **Calculate the VIKOR Index:** For each alternative, compute: [6] $Q_j = v\frac{(S_j - S^*)}{(S^- - S^*)} + (1-v)\frac{(R_j - R^*)}{(R^- - R^*)}$
Where, S^* = min (Roy et al.), S^- = max(Roy et al.), R^* = min $\{R_j\}$, R^- = max $\{R_j\}$, and v is the weight assigned to the strategy of maximizing group utility, while $1 - v$ represents the weight of minimizing individual regret. The value of v is typically set to 0.5 (Chang, 2010).

5. **Rank Alternatives:** The alternative with the lowest Q_j is selected as the optimal compromise solution (Chang, 2010).

4. RESULT AND DISCUSSION

4.1 Selection Criteria Weight

The study received 36 responses from 100 invitations, resulting in a response rate of 36%. After excluding 4 incomplete entries, 32 complete responses were analyzed. According to Morton et al. (2012), the average response rate for academic surveys is 55.6%, with a standard deviation of ±19.7%, indicating a minimum expected threshold of approximately 35.9%. While our final response rate is slightly below this minimum, it remains within a marginal and acceptable range for exploratory research involving industry professionals. However, we acknowledge that a lower response rate may limit the generalizability of findings and introduce non-response bias if the perspectives of participants differ systematically from those who did not respond. To minimize this risk, the final sample includes a balanced distribution of respondents across ownership, design, and construction roles, with varied years of experience. Additionally, sensitivity analysis and real-world case study validation were conducted to verify the stability and practical relevance of the results. The participants' profiles are summarized in Table 4.

Table 4: Participants Information

Affiliation	Years of experience	Number	Percentage (%)
Owner	Less than 5 years	2	6.25
	Between 5 and 10 years	4	12.5
	More than 10	2	6.25
Constructor	Less than 5 years	3	9.375
	Between 5 and 10 years	7	21.875
	More than 10	5	15.625
Designer	Less than 5 years	4	12.5
	Between 5 and 10 years	3	9.375
	More than 10	2	6.25

These 32 expert responses were used to evaluate the significance of various criteria and the effectiveness of different PDMs on a qualitative scale. The qualitative assessments were converted to numerical values, normalized (using Equation 1), and the resulting weights are presented in Table 5. The highest weight was given to "Manage budget and minimize risks" (0.175), followed by "Involve key stakeholders early" (0.149) and "Define project scope and adapt" (0.131). These findings align with the literature, which emphasizes the importance of proactive budget and risk management, early stakeholder engagement, and adaptable project scopes—especially in sustainable construction projects. Other critical criteria include achieving sustainability certifications, managing complexity and coordination, fostering teamwork, facilitating procurement, and incorporating innovation and flexible contracts. Collectively, these criteria ensure that the selected PDM supports timely, cost-effective project completion while meeting essential sustainability standards.

Table 5: Normalized Weight (Wi) per criteria gathered from the first survey

Criteria	**Weight**
Manage budget and minimize risks	0.175
Involve key stakeholders early	0.149
Define project scope and adapt	0.131
Achieve sustainability certifications	0.094
Manage complexity and coordination	0.086
Foster teamwork and communication	0.070
Facilitate procurement	0.062
Ensure timely project completion	0.062
Encourage innovation with rewards	0.055
Set early sustainability benchmarks	0.050
Align contracts with sustainability	0.045
Structure flexible contracts	0.021

4.2 Effectiveness of PDMs

Table 6 shows the normalized effectiveness scores from the second survey for four PDMs—DBB, CMAR, IPD, and DB. Using the VIKOR method, the ideal (fi*) and negative-ideal (fi-) solutions were identified, followed by the calculation of utility (Sj) and regret (Rj) measures. With the criteria weights from Table 5, the VIKOR index (Qj) was computed (Equation 8) by normalizing and aggregating these scores to compare the overall effectiveness of each PDM.

Table 6: Normalized effectiveness scores for each criterion across the PDMs

Criteria	DB	IPD	CMR	DBB
Manage budget and minimize risks	0,88	0,63	0,75	1,00
Ensure timely project completion	0,89	1,00	0,78	0,67
Facilitate procurement	1,00	0,89	0,67	0,56
Define project scope and adapt	0,78	1,00	0,67	0,44
Manage complexity and coordination	0,78	1,00	0,89	0,67
Involve key stakeholders early	0,78	1,00	0,89	0,56
Foster teamwork and communication	0,67	1,00	0,89	0,44
Achieve sustainability certifications	0,67	1,00	0,78	0,56
Set early sustainability benchmarks	0,56	1,00	0,78	0,44
Encourage innovation with rewards	0,67	1,00	0,78	0,33
Structure flexible contracts	0,78	1,00	0,67	0,44
Align contracts with sustainability	0,67	1,00	0,78	0,33

5. CASE STUDY

This study validates the framework using two projects—one successful and one unsuccessful. Stakeholders from each project evaluated key criteria, and the framework's recommended PDM was compared to the actual method used.

5.1 Overview of the Projects

Two projects were selected: King Abdullah University of Science and Technology (KAUST) and the Jeddah Tower in Saudi Arabia. KAUST, which used a Design-Build approach, was completed on time and within budget, achieving LEED Platinum and setting sustainability benchmarks. In contrast, Jeddah Tower, using Design-Bid-Build, faced significant delays and did not meet its initial objectives. Table 7 provides a comparative overview of key aspects for each project. The data is sourced from FORMAN (2024); HOK (2024).

Table 7: Comparative Overview of KAUST and Jeddah Tower Projects

Aspect	Project A: KAUST	Project B: Jeddah Tower
Objective	Develop a globally competitive, student-centered research campus.	Construct the world's tallest building as an architectural and engineering landmark.
Timeline	2007–2009 (≈2.5 years; completed on time).	Started in 2013; initially planned for 2020; currently facing significant delays.
Stakeholders	Client: Saudi Government Design: HOK Group Contractors: Saudi Aramco, SBG, Saudi Oger	Developer: Jeddah Economic Company Architect: Adrian Smith + Gordon Gill Architecture Contractor: SBG
Delivery Method	Design-Build (DB)	Design-Bid-Build
Outcomes	Completed on time and budget, achieved LEED Platinum, and set sustainability benchmarks.	Experienced multiple setbacks and delays, failing to meet initial project objectives.
Key Challenges	Tight timeline and complex sustainability requirements.	Financial, logistical, and legal issues.

5.2 Data Collection and Stakeholder Input

Fifteen stakeholders—nine from KAUST and six from Jeddah Tower—were interviewed and surveyed. They rated the criteria of cost, time, quality, risk, flexibility, integration, and sustainability; KAUST participants placed greatest emphasis on procurement efficiency, timely completion, budget control, complexity management, and sustainability certifications, whereas Jeddah Tower participants highlighted complexity, procurement, and timely completion. Their weightings are summarised in Table 8. The effectiveness ratings of the four PDMs, however, remained identical to those shown earlier in Table 6; only the criterion-weight vectors were replaced by these stakeholder-specific values so that the decision-support system's sensitivity to changing priorities—rather than to altered performance scores—could be assessed.

Table 8: Importance Levels of Criteria Assigned by KAUST and Jeddah Tower Stakeholders

Criterion	Importance Level (KAUST)	Importance Level (Jeddah Tower)
Manage Budget	High	Medium
Ensure Timely Completion	High	High
Facilitate Procurement	Very High	High
Define Project Scope	Low	Low
Manage Complexity	High	High
Involve Stakeholders Early	Low	Medium
Foster Teamwork	Medium	Medium
Achieve Sustainability Certifications	High	Medium
Set Sustainability Benchmarks	High	Low
Encourage Innovation	Medium	Medium
Structure Flexible Contracts	Medium	Medium
Align Contracts with Sustainability	High	Medium

5.3 Framework Application and Evaluation

The framework was applied to the KAUST and Jeddah Tower projects using stakeholder-defined criteria weights. Figure 2 shows the VIKOR index rankings for each project. For KAUST, DB had the lowest VIKOR index, making it the optimal choice. Stakeholders prioritized efficient procurement, timely completion, budget and complexity management, sustainability certifications, and contract alignment—criteria that supported the actual use of DB. For Jeddah Tower, the framework identified IPD as the best option, with CMR as a close second. Key criteria included managing complexity, timely completion, procurement, early stakeholder involvement, and contract flexibility. However, the project used DBB, which likely contributed to its delays and challenges.

Figure 2: VIKOR Index Rankings of PDMs for (a) KAUST, and (b) Jeddah Tower project

While both projects were executed in the same country, their differing contexts likely influenced the selection of different PDMs. KAUST, a high-profile institutional project with tight deadlines and a clear sustainability agenda, benefited from centralized oversight and government facilitation—conditions favorable to the streamlined coordination of Design–Build. On the other hand, Jeddah Tower, envisioned as the world’s tallest building, involved multiple stakeholders, a longer timeline, and greater technical and financial uncertainties, which may have encouraged the use of the more traditional Design–Bid–Build approach. Factors such as organizational culture, supply chain maturity, and legacy procurement norms may also have played a role. These contextual differences support the need for a flexible, criteria-based decision-support framework capable of adapting to diverse project environments.

6. CONCLUSION

This study introduced a decision-support tool designed to select the most suitable Project Delivery Method (PDM) for sustainable construction projects. The tool addresses the critical challenge of aligning project delivery methods with sustainability objectives by integrating expert insights, stakeholder preferences, and sustainability-specific criteria. A comprehensive list of important criteria for sustainable construction was initially derived from existing literature and then refined through consultations with experts. To prioritize these criteria, a survey was conducted among professionals with expertise in sustainable projects, assigning weights based on their relative importance. Additionally, the study identified four commonly used PDMs (i.e., design–bid–build (DBB), design–build (DB), construction management at risk (CMR), and integrated project delivery (IPD)) and assessed their effectiveness in achieving sustainability objectives. This evaluation was conducted through a second survey of experts in the field. The collected data formed the basis for the framework’s development. The VIKOR method was employed to integrate both group utility and individual preferences, offering a balanced and systematic approach to PDM selection. The practical application of the framework was evaluated using two real-world case studies. In the first case, the Design-Build (DB) method, recommended by the framework, was successfully implemented. This method aligned with stakeholder priorities and contributed to positive outcomes, including timely completion and meeting sustainability benchmarks. In the second case, the Jeddah Tower project, the framework recommended the Integrated Project Delivery (IPD) method. This recommendation underscored the potential benefits of a more collaborative approach, highlighting how IPD could address complex stakeholder objectives and mitigate risks more effectively than the previously employed Design-Bid-Build (DBB) approach.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the invaluable contributions that made this research possible. We extend our sincere thanks to the industry professionals, construction experts, and project stakeholders who participated in our surveys and interviews, offering critical insights that helped shape both the development and validation of our decision-support tool. We are particularly appreciative of the project teams at King Abdullah University of Science and Technology (KAUST) and the Jeddah Tower, whose willingness to share practical experiences enriched our case studies and provided real-world context to our findings. We also wish to acknowledge the continuous support and guidance from our colleagues and mentors at the Department of Civil and Environmental Engineering, University of Alberta. Finally, we thank the design engineers, project engineers, contractors, and owners whose practical perspectives and collaborative spirit have been essential to advancing sustainable construction practices through this work.

REFERENCES

Agbaxode, P. D. K., Saghatforoush, E., Dlamini, S., & Korsah, J. K. (2024). Integrated project delivery enablers to enhance conventional project delivery toward improving design documentation quality. *Built Environment Project and Asset Management*.

Ahmed, I., Feng, B., Abdul, D., & Feng, J. (2022). A Hybrid Fuzzy AHP/VIKOR Approach to Funding Strategy Selection for Advanced Prosthetic and Orthotic Medical Devices in Low-Income Countries: A Case of Pakistan. *Mathematical Problems in Engineering*, *2022*(1), 2153940.

Ahmed, M. N., Aswed, G. K., & Mohammed, H. A. (2024). Decision-Making for Project Delivery System in Construction Projects Based on SWARA-TOPSIS Methods. *Tikrit Journal of Engineering Sciences*, *31*(1), 306-313.

Ahmed, S., & El-Sayegh, S. (2020). Critical review of the evolution of project delivery methods in the construction industry. *Buildings*, *11*(1), 11.

Ahmed, S., & El-Sayegh, S. (2021). Critical Review of the Evolution of Project Delivery Methods in the Construction Industry. *Buildings*, *11*(1), 11. https://www.mdpi.com/2075-5309/11/1/11

Ahmed, S., & El-Sayegh, S. (2024). Relevant criteria for selecting project delivery methods in sustainable construction. *International Journal of Construction Management*, *24*(5), 512-520.

Al Khalil, M. I. (2002). Selecting the appropriate project delivery method using AHP. *International journal of project management*, *20*(6), 469-474.

Alleman, D., Antoine, A., Papajohn, D., & Molenaar, K. (2017). Desired versus realized benefits of alternative contracting methods on extreme value highway projects. *Proc., Resilient Structures and Sustainable Construction*, 1-6.

An, X., Wang, Z., Li, H., & Ding, J. (2018). Project delivery system selection with interval-valued intuitionistic fuzzy set group decision-making method. *Group Decision and Negotiation*, *27*, 689-707.

Antoine, A. L., Alleman, D., & Molenaar, K. R. (2019). Examination of project duration, project intensity, and timing of cost certainty in highway project delivery methods. *Journal of management in engineering*, *35*(1), 04018049.

Boran, F. E. (2011). An integrated intuitionistic fuzzy multi criteria decision making method for facility location selection. *Mathematical and Computational Applications*, *16*(2), 487-496.

Brahmi, B. F., Sassi Boudemagh, S., Kitouni, I., & Kamari, A. (2022). IPD and BIM-focussed methodology in renovation of heritage buildings. *Construction management and economics*, *40*(3), 186-206.

Chang, C.-L. (2010). A modified VIKOR method for multiple criteria analysis. *Environmental monitoring and assessment*, *168*, 339-344.

Chen, Y. Q., Liu, J. Y., Li, B., & Lin, B. (2011). Project delivery system selection of construction projects in China. *Expert Systems with Applications*, *38*(5), 5456-5462.

Demetracopoulou, V., O'Brien, W. J., & Khwaja, N. (2020). Lessons learned from selection of project delivery methods in highway projects: The Texas experience. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *12*(1), 04519040.

Engebø, A., Lædre, O., Young, B., Larssen, P. F., Lohne, J., & Klakegg, O. J. (2020). Collaborative project delivery methods: A scoping review. *Journal of Civil Engineering and Management*, *26*(3), 278-303.

Feghaly, J., El Asmar, M., Ariaratnam, S., & Bearup, W. (2020). Selecting project delivery methods for water treatment plants. *Engineering, Construction and Architectural Management*, *27*(4), 936-951.

FORMAN, C. (2024). *Contractor appointed to complete world's tallest tower*.

Gunhan, S. (2019). Analyzing sustainable building construction project delivery practices: builders' perspective. *Practice periodical on structural design and construction*, *24*(1), 05018003.

He, H., Gan, X., Liu, L., & Zhang, X. (2024). Adaptability Analysis of Integrated Project Delivery Method in Large- and Medium-Sized Engineering Projects: A FAHP-Based Modeling Solution. *Buildings*, *14*(7), 1999. https://www.mdpi.com/2075-5309/14/7/1999

HOK. (2024). *King Abdullah University of Science and Technology | Thuwal, Saudi Arabia*. Retrieved November from

Khwaja, N., O'Brien, W. J., Martinez, M., Sankaran, B., O'Connor, J. T., & "Bill" Hale, W. (2018). Innovations in project delivery method selection approach in the Texas Department of Transportation. *Journal of management in engineering*, *34*(6), 05018010.

Larsson, J., Eriksson, P. E., Lingegård, S., & Järvenpää, A.-T. (2022). Innovation outcomes and processes in infrastructure projects–a comparative study of Design-Build and Design-Build-Maintenance contracts. *Construction management and economics*, *40*(2), 142-156.

Li, H., Qin, K., & Li, P. (2015). Selection of project delivery approach with unascertained model. *Kybernetes*, *44*(2), 238-252.

Li, H., Su, L., Cao, Y., & Lv, L. (2019). A pythagorean fuzzy TOPSIS method based on similarity measure and its application to project delivery system selection. *Journal of Intelligent & Fuzzy Systems*, *37*(5), 7059-7071.

Martin, H., Lewis, T. M., & Petersen, A. (2016). Factors affecting the choice of construction project delivery in developing oil and gas economies. *Architectural Engineering and Design Management*, *12*(3), 170-188.

Mostafavi, A., & Karamouz, M. (2010). Selecting appropriate project delivery system: Fuzzy approach with risk analysis. *Journal of Construction Engineering and Management*, *136*(8), 923-930.

Nguyen, P. H., Tran, D., & Lines, B. C. (2020). Fuzzy set theory approach to classify highway project characteristics for delivery selection. *Journal of Construction Engineering and Management*, *146*(5), 04020044.

Noorzai, E. (2020). Performance analysis of alternative contracting methods for highway construction projects: Case study for Iran. *Journal of Infrastructure Systems*, *26*(2), 04020003.

Opricovic, S., & Tzeng, G.-H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European journal of operational research*, *156*(2), 445-455.

Programme, U. N. E. (2022). *2022 Global Status Report for Buildings and Construction: Towards a Zero‑emission, Efficient and Resilient Buildings and Construction Sector.* U. N. E. Programme.

Qiang, M., Wen, Q., Jiang, H., & Yuan, S. (2015). Factors governing construction project delivery selection: A content analysis. *International journal of project management*, *33*(8), 1780-1794.

Robichaud, L. B., & Anantatmula, V. S. (2011). Greening project management practices for sustainable construction. *Journal of management in engineering*, *27*(1), 48-57.

Roy, V., Desjardins, D., Ouellet-Plamondon, C., & Fertel, C. (2021). Reflection on integrity management while engaging with third parties in the construction and civil engineering industry. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *13*(1), 03720005.

Ruparathna, R., & Hewage, K. (2015a). Sustainable procurement in the Canadian construction industry: challenges and benefits. *Canadian Journal of Civil Engineering*, *42*(6), 417-426.

Ruparathna, R., & Hewage, K. (2015b). Sustainable procurement in the Canadian construction industry: current practices, drivers and opportunities. *Journal of Cleaner Production*, *109*, 305-314.

Shahrokhishahraki, M., M. Malekpour, S. Mirvalad, and G. Faraone. (2024a). Machine learning predictions for optimal cement content in sustainable concrete constructions. *Journal of Building Engineering, 82*. Elsevier Ltd. https://doi.org/10.1016/j.jobe.2023.108160.

Shahrokhishahraki M., Rezaeiashtiani M. R., Golabchi H., Mohamed Y., Lee G. (2024b). Feasibility Test of a Hybrid Simulation Approach for Optimized Resource Allocation and Cash Flow Management. *Proceedings of the 23rd International Conference on Modeling & Applied Simulation (MAS 2024), 011*. DOI: https://doi.org/10.46354/i3m.2024.mas.011

Silvius, A. G., & Schipper, R. P. (2014). Sustainability in project management competencies: analyzing the competence gap of project managers. *Journal of Human Resource and Sustainability Studies*, *2014*.

Švajlenka, J., Kozlovská, M., & Pošiváková, T. (2018). Analysis of selected building constructions used in industrial construction in terms of sustainability benefits. *Sustainability*, *10*(12), 4394.

Swarup, L., Korkmaz, S., & Riley, D. (2011). Project delivery metrics for sustainable, high-performance buildings. *Journal of Construction Engineering and Management*, *137*(12), 1043-1051.

Taherdoost, H., & Madanchian, M. (2023). VIKOR Method—An Effective Compromising Ranking Technique for Decision Making. *Taherdoost, H., Madanchian, M*, 27-33.

Xia, B., Chan, A. P., & Yeung, J. F. (2011). Developing a fuzzy multicriteria decision-making model for selecting design-build operational variations. *Journal of Construction Engineering and Management*, *137*(12), 1176-1184.

Zhang, J., Chen, F., & Yuan, X.-X. (2020). Comparison of cost and schedule performance of large public projects under P3 and traditional delivery models: A Canadian study. *Construction management and economics*, *38*(8), 739-755.

Zhong, Q., Tang, H., & Chen, C. (2022). A framework for selecting construction project delivery method using design structure matrix. *Buildings*, *12*(4), 443.

Zhu, X., Meng, X., & Chen, Y. (2020). A novel decision-making model for selecting a construction project delivery system. *Journal of Civil Engineering and Management*, *26*(7), 635-650.