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A Delphi survey

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Identification of critical soft cost elements in BIM-based construction projects: a Delphi survey

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Abstract

Purpose – Building information modeling (BIM) offers numerous benefits for construction projects, but its implementation can include additional non-physical costs, commonly referred to as soft costs, distinct from traditional construction projects. Hence, understanding the soft cost elements (SCEs) is critical for accurate cost estimation in BIM-based construction projects. This study aims to identify the critical SCEs in BIM-based construction projects.

Design/methodology/approach – This study conducted a multi-stage approach, starting with an SLR to compile an initial list of SCEs, which was refined through a pilot test with BIM experts. A Delphi survey conducted with 16 experts evaluated the SCEs for two rounds. Data analysis included mean values and percentage of agreement analyses to identify the critical SCEs. Finally, a thematic analysis was conducted to categorize the critical SCEs.

Findings – This study identified eight critical SCEs in BIM-based construction projects, categorized into two categories: technology and human resources. Technology-related costs include BIM software, hardware, updates and BIM-specific planning/designing. Human resource-related costs encompass BIM consultant, modeler, coordinator and manager remuneration.

Originality/value – This is the first study to determine the critical SCEs in BIM-based construction projects. Understanding the critical SCEs provides stakeholders with actionable insights for developing strategies to improve the cost management of SCEs in BIM-based construction projects.

Keywords Building information modeling (BIM), Soft costs, Construction projects,
Systematic literature review, Delphi survey

Paper type Research article

1. Introduction

Building Information Modeling (BIM) is becoming a transformative methodology in the construction industry, offering a digital representation of a facility's physical and functional characteristics (Farouk and Rahman, 2023). It integrates intelligent 3D models to support decision-making across planning, design, construction, and operation phases (Syed Jamaludin *et al.*, 2022). Although BIM enhances collaboration, visualization, and resource efficiency, its implementation introduces additional non-physical costs (i.e. soft costs) distinct from traditional

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construction projects. These include software licensing, staff training, and data management. Research suggests soft costs can constitute up to 40% of a BIM-based construction project cost, making their effective management critical to project profitability (Abidin and Azizi, 2021; Farouk and Rahman, 2023). Poor oversight of soft costs can lead to budget overruns due to costs such as excessive software licensing fees, inefficient coordination workflows, and limited software interoperability (Abidin and Azizi, 2021). Moreover, costs associated with maintaining data environments, upskilling personnel in BIM workflows, and addressing unforeseen BIM implementation challenges further contribute to the overall soft costs (Anireddy, 2023).

To mitigate the financial risks associated with BIM, project stakeholders must identify critical soft cost elements (SCEs) and implement targeted management strategies. These include negotiating optimized software licensing agreements, instituting structured staff training programs, deploying data governance frameworks, and investing in interoperability tools that enhance cross-disciplinary coordination. Such strategies are critical for minimizing the cumulative soft costs incurred throughout BIM-based construction projects. In contrast, the absence of these strategies can result in inefficient workflows, extended project durations, and budget overruns, which are detrimental to projects operating under financial constraints (Rostamiasl and Jrade, 2024). Managing SCEs effectively is a strategic requirement for achieving sustainable project outcomes. Inadequate oversight of SCEs can erode project margins, diminish return on investment (ROI), and elevate financial and operational exposure, especially for small and medium enterprises (SMEs) (Zhang *et al.*, 2023). As BIM continues to gain traction across diverse construction typologies and geographic markets, accurately managing SCEs is critical for securing the competitive advantage of BIM-based construction projects (Rostamiasl and Jrade, 2024).

Despite the growing implementation of BIM, some organizations remain hesitant due to uncertainties surrounding the ROI associated with its implementation (Zhang *et al.*, 2023). These uncertainties often lead to delays in BIM implementation. A contributor to this uncertainty is the challenge of estimating soft costs, such as software licensing and staff training, that are integral to BIM (Fateh and Aziz, 2022). Incorporating SCEs into ROI calculations is critical for a holistic assessment of BIM's economic impact (Fateh and Aziz, 2022). Research has shown that these costs can constitute a substantial portion of construction project costs, and mismanagement can affect project profitability (Rostamiasl and Jrade, 2024). Moreover, organizations that overlook BIM will miss opportunities for improved collaboration, enhanced project visualization, and increased efficiency in resource allocation (Van Tam *et al.*, 2023). To address these concerns, project stakeholders should evaluate potential SCEs and gain an understanding of the ROI associated with BIM implementation (Zhang *et al.*, 2023). This evaluation enables informed decision-making, minimizes financial risks, and facilitates better navigation through the complexities of BIM implementation (Zhang *et al.*, 2023).

Accurate management of SCEs is critical for ensuring the financial viability of BIM-based construction projects. Comprehensive evaluation and early integration of SCEs into cost-planning allow project stakeholders to pinpoint cost-intensive activities, enhance operational efficiency, and mitigate unnecessary expenditures (Das *et al.*, 2025). Effective management of SCEs enables more strategic resource allocation, minimizes rework arising from coordination failures, and supports consistent delivery of project objectives. Furthermore, prioritizing SCEs during the planning stages improves cost estimation accuracy, enabling more reliable ROI calculations and reducing exposure to financial risks (Fazeli *et al.*, 2021). As BIM continues to expand globally, an understanding of SCEs is critical.

To successfully estimate soft costs in BIM-based construction projects, it is essential to determine the critical SCEs. This study aims to identify the critical SCEs in BIM-based construction projects. By achieving that aim, this study contributes to the broader implementation of BIM in the construction industry. Accurate estimation of soft costs in BIM-based construction projects can improve cost control, reduce financial risks, and enhance overall project management. This, in turn, encourages BIM implementation, leading to increased efficiency, productivity, and competitiveness in the construction industry. Notably, this is the first study to determine the critical SCEs in BIM-based construction projects.

2. Research background

2.1 Economic challenges of BIM

BIM offers benefits in terms of efficiency, risk mitigation, and cost control. By facilitating a comprehensive digital representation of construction projects, BIM enables visualizations, real-time information sharing, and improved stakeholder coordination. These capabilities contribute to streamlined workflows, reduced rework, and more reliable cost estimation and control throughout a project's lifecycle (Farouk and Rahman, 2023). Furthermore, BIM fosters transparency by providing clear visibility into cost structures, scheduling constraints, and constructability challenges.

Despite its benefits, the cost associated with BIM implementation presents a persistent challenge, particularly for SMEs. Critical costs include software licensing, specialized hardware requirements, extensive staff training, higher remuneration for BIM professionals, and consultancy services (Fateh and Aziz, 2022). These costs do not directly contribute to physical construction but are critical for the success of BIM-based construction projects, undermining the economic feasibility of BIM implementation (Fateh and Aziz, 2022).

To overcome these challenges, there is a need for research into scalable, cost-effective implementation models, including exploring cloud-based BIM solutions that minimize hardware dependency, standardized competency-based training programs to reduce onboarding costs, and performance-based remuneration frameworks for BIM professionals. Understanding these costs is critical to unlocking the full potential of BIM and ensuring its widespread and sustainable implementation across construction projects (Fazeli *et al.*, 2021).

2.2 Soft cost estimation of construction projects

Soft costs represent a critical dimension of construction project success, particularly in budgeting accuracy, risk mitigation, and strategic financial decision-making. Abidin and Azizi (2021) categorized SCEs of construction projects into design influence, authority requirements, and development provisions and highlighted that, although these costs account for a small portion of project cost, their impact on project planning, execution, and outcomes is substantial. Research has further explored soft cost estimation complexities, revealing gaps between theoretical approaches and practical applications. In particular, the absence of standardized frameworks is a major challenge. Anireddy (2023) reinforced the criticality of early and accurate estimation of soft costs, such as design fees, permitting charges, and insurance premiums, and recommended strategic partnerships, contingency fund allocation, and the usage of innovative tools to improve estimation accuracy. Similarly, Fazil *et al.* (2024) emphasized the role of organizational controls, comprising structured workflows and accountability systems, in improving soft cost estimation.

Recent research also highlights the role of BIM in improving cost estimation. Das *et al.* (2025) demonstrated that BIM improves cost estimation by minimizing design errors and enhancing coordination. Pishdad and Onungwa (2024) showed the potential of 5D BIM in improving cost estimation by synchronizing cost data with project schedules and payment structures. Cassandro *et al.* (2024) proposed an Industry Foundation Classes (IFC)-based framework to automate and improve cost estimation accuracy. Rostamiasl and Jrade (2024) developed a BIM–Life Cycle Cost Analysis (LCCA) model to improve early-stage cost estimation in residential construction projects. Zhao (2024) further illustrated how BIM can improve cost estimation through project visualization and decision-making analytics.

2.3 Research gap and study positioning

Despite extensive research into cost elements of construction projects, including the economic challenges of BIM implementation and its application in cost estimation workflows, a research gap remains in identifying the critical SCEs specific to BIM-based construction projects. Although existing research has explored overarching SCEs, such as software licensing, hardware upgrades, professional training, and consultancy services, it has predominantly addressed these issues at a macro level. Similarly, research on 5D BIM and LCCA has advanced an understanding of cost modeling, yet it has not delineated the critical SCEs in BIM-based construction projects. This gap is crucial given the centrality of BIM in cost estimation frameworks. To address this gap, this study aims to identify the critical SCEs in BIM-based construction projects.

3. Methodology

The core of the study methodology comprised a Delphi survey, a method widely recognized for its effectiveness in achieving consensus on critical variables of emerging topics. The method involves experts who anonymously complete a series of surveys over multiple rounds, enabling a convergence of informed opinions and structured consensus-building. Variability in consensus is an inherent aspect of the Delphi method, often arising from the diverse professional backgrounds and the complexity of the subject matter. As experts review aggregated responses and refine their judgments in subsequent rounds, their opinions tend to converge, enhancing the reliability and validity of the consensus on critical variables. This iterative refinement is a strength of the Delphi method, facilitating informed agreement despite initial disparities. Prior research, including Ogunbayo *et al*. (2022), Ahiabu *et al*. (2023), and Abu Arqoub *et al*. (2023), used the Delphi method to identify critical cost elements in building maintenance, critical benefits of sustainable construction, and critical factors affecting end-user satisfaction in built environment projects, respectively, demonstrating the effective use of the method to identify critical variables in construction project management research.

To conduct the Delphi survey, first, a systematic literature review (SLR) was undertaken to compile an initial list of SCEs. Next, a pilot test was administered to BIM experts to eliminate irrelevant SCEs lacking relevance and incorporate new elements. After finalizing the list of SCEs, the Delphi survey was prepared. The final list consisted of 38 elements, 31 from the SLR and 7 from the pilot test. The Delphi survey consisted of two rounds to determine the critical SCEs in BIM-based construction projects. Statistical analysis included mean and percentage of agreement (POA). Figure 1 illustrates the research flow. The upcoming subsections detail the research flow.

3.1 Data preparation

3.1.1 Systematic literature review. The SLR was conducted using Scopus, chosen for its extensive coverage and superior indexing accuracy relative to Web of Science and Google Scholar, respectively (Martín-Martín *et al*., 2018). The initial search, conducted on July 22, 2022, used the “title/abstract/keyword” feature with the search string: KEY (construction) TITLE-ABS-KEY (“soft cost” OR “indirect cost” OR “overhead cost”) AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (LANGUAGE, “English”)). To ensure the relevance and quality of the articles, specific inclusion and exclusion criteria were developed based on two main questions: (1) Is the article relevant to the study aim? (2) Is the article applicable for review? The criteria were as follows: only journal articles published in English were included, and conference proceedings, book chapters, review articles, books, and non-English articles were excluded. This search criteria is crucial for maintaining the quality of the SLR (Meline, 2006). As a result, 149 articles were identified. The titles and abstracts of these articles were then screened for relevance to soft costs, leading to the selection of 28 articles for full-text reviews. Of these, eight articles met the relevance and methodological thresholds. To enhance comprehensiveness, forward and backward snowballing (Wohlin, 2014) was applied over four iterative cycles until no new articles emerged, adding six articles for a final sample of 14. The selected articles were subjected to thematic analysis using an inductive coding scheme to extract SCEs. These steps, including article identification, screening, eligibility, and inclusion, were aligned with the PRISMA guidelines to ensure transparency and reproducibility of the SLR.

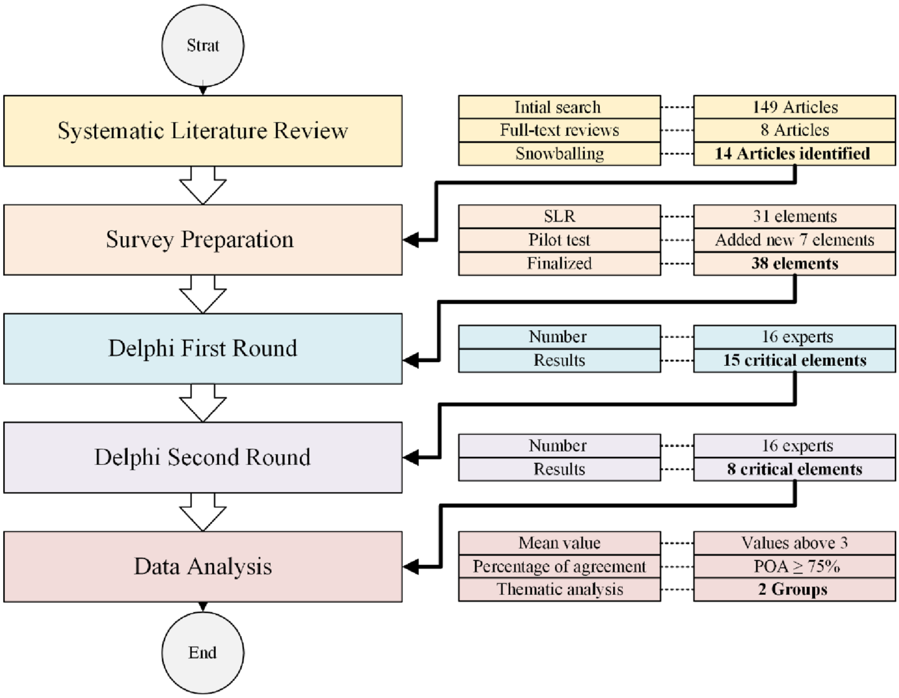

Figure 1. Research flow. Source: Authors' own work

3.1.2 Pilot test. Then, a pilot test involving BIM experts was conducted to ensure the reliability of the identified SCEs, as recommended by Morin (2013). This phase examined the SCEs for clarity, impartiality, and response accuracy. The pilot test played a crucial role in detecting ambiguities and ensuring the manageability of the survey instrument, thereby promoting sustained engagement during the main data collection (Kezar and Maxey, 2016). Additionally, the feedback obtained contributed to refining the study design and improving the interpretability of the results, consistent with best practices for enhancing reliability and validity (Abd Wahab *et al*., 2023). Based on the acquired feedback, the list of SCEs was refined by removing ten elements deemed irrelevant or redundant and introducing eight new elements to capture the subject matter better. This process resulted in a finalized set of 38 SCEs (as listed in Table 1), which was subsequently deployed in the Delphi survey.

3.2 Data collection

The Delphi survey plays a foundational component in the methodology, with emphasis placed on expert selection based on their technical expertise and practical experience. Prior research asserts that the Delphi survey should include a minimum of seven experts and encompass a broad range of knowledge and experience to ensure analytical robustness and minimize the risk of groupthink (Hohmann *et al*., 2018). The structured and iterative nature of the Delphi method is critical for facilitating consensus building, with a consensus threshold of 70% or greater as a standard benchmark for validity and reliability (Kezar and Maxey, 2016). Anonymity is maintained throughout all survey rounds to mitigate social desirability bias and cognitive anchoring effects, thereby enhancing the objectivity and credibility of the responses. Aggregated feedback is also systematically provided after each round, enabling experts to refine their evaluations based on evolving group perspectives, which is fundamental to the

Table 1. Final soft cost elements

Code	Elements	Source
C01	Conveyance at site	[1]–[3]
C02	Mobilization	[1]–[4]
C03	Off/on-site logistics	[1]–[3]
C04	Testing materials	[1]–[3], [5]
C05	Construction camp	[1], [4]–[6]
C06	Roadways at construction site	[1], [3], [4]
C07	Site utilities	[1], [4], [5]
C08	Interim Finance	[1], [4]–[7]
C09	Development charges	[1], [2], [5]–[8]
C10	Certification fees	[1], [2], [5]–[8]
C11	Commissioning fees	[5], [6], [8]
C12	Contingency fees	[2], [5]–[8]
C13	Levy fees	[5], [6], [8]
C14	Documentation fees	[2], [6], [8], [9]
C15	Environmental specialist remuneration	[1]–[3], [7], [8]
C16	Chief warehouseman remuneration	[1]–[3]
C17	Field engineer remuneration	[1]–[4], [8]
C18	General superintendent remuneration	[2], [3], [5], [8]
C19	Landscape architect remuneration	[1]–[3], [7], [8]
C20	Materials engineer remuneration	[1]–[4], [8]
C21	Safety engineer remuneration	[1]–[4], [8]
C22	Soil analyst remuneration	[1], [2], [4], [7], [8]
C23	Surveyor remuneration	[1]–[4], [7], [8]
C24	Construction manager remuneration	[1]–[4], [7], [8]
C25	Consultant remuneration	[2]–[4], [6]–[8]
C26	Cost engineer remuneration	[1]–[3], [7], [8], [10]
C27	Quality assurance/quality control engineer remuneration	[1]–[3], [6], [8], [11]
C28	Schedule engineer remuneration	[2], [3], [8]
C29	Drawings costs	[2], [3], [6], [8], [12], [13]
C30	Energy modeling costs	[2], [6], [8], [14]
C31	Planning/designing cost	[2], [3], [6], [8], [9], [15]
C32	BIM software overhead	Pilot study
C33	BIM consultant remuneration	Pilot study
C34	BIM model updates	Pilot study
C35	BIM hardware overhead	Pilot study
C36	BIM modeler	Pilot study
C37	BIM coordinator	Pilot study
C38	BIM manager	Pilot study

Note(s): 1: Saini *et al.* (2021), 2: Abidin and Azizi (2021), 3: Holland and Jr (1999), 4: Said *et al.* (2009), 5: Hu and Skibniewski (2021a), 6: Hu and Skibniewski (2021b), 7: Azizi *et al.* (2015), 8: Alshboul *et al.* (2022), 9: Zhang and Touran (2012), 10: Patre and Ugale (2020), 11: Ade and Rehm (2020), 12: Silombela *et al.* (2018), 13: Abidin and Azizi (2016), 14: Zahirah *et al.* (2013), 15: Nurul Zahirah and Abidin (2012)

Source(s): Authors' own work

methodological rigor of the Delphi method. Incorporating Likert scales can support the systematic and quantitative capture of expert judgments, drawing on their proven reliability and validity in measuring attitudes and perceptions. In alignment with best practices, two to three Delphi rounds are necessary to optimize consensus formation and sustain expert engagement. Furthermore, diversity in disciplinary background and professional tenure can enhance the robustness, credibility, and generalizability of the study findings (Kezar and Maxey, 2016).

The data collection employed a nonprobability sampling approach to recruit experts, recognizing its practicality for accessing specialized and context-specific expertise. However, given the potential for selection bias inherent to nonprobability sampling, a purposive sampling technique was used to select experts with demonstrated engagement in the subject matter (Campbell *et al.*, 2020). Eligibility criteria require fulfilling at least two of the following conditions: (1) extensive professional experience (minimum five years) in the construction industry, (2) active involvement in at least one BIM-based construction project within the last five years, or (3) demonstrable expertise in BIM principles, tools, and methodologies. The expert selection was undertaken through a multi-step purposive sampling technique to ensure methodological rigor and contextual relevance (Campbell *et al.*, 2020). Potential experts were identified and vetted using the LinkedIn platform, which enabled the verification of BIM-specific expertise and ensured direct involvement in BIM-based construction projects (Kezar and Maxey, 2016).

The data collection involves 16 experts, aligning with established recommendations that advocate for 7 to 15 experts to balance expertise diversity with operational manageability (Hohmann *et al.*, 2018). Among them, 75% had a minimum of five years of dedicated BIM experience, while the remaining 25% brought over 2 decades of construction management expertise, offering a comprehensive and balanced perspective crucial for achieving credible consensus outcomes. This composition is consistent with standards reported in prior Delphi research on construction project management, thereby reinforcing the comparability and validity of the findings (Jones and Jones, 2018; Olawumi and Chan, 2018). Detailed information of the experts is provided in Table 2.

3.3 Data analysis

3.3.1 Mean values. To determine consensus in this study, two primary criteria were adopted. The first criterion is based on the average mean value of expert responses. A mean value of 3.0 or higher on a 5-point Likert scale was used as the minimum threshold for agreement among experts. This threshold has been widely adopted in Delphi-related research in the engineering and project management fields. Chan (2022) mentioned that a mean score of 3.0 and above determines acceptance and provides a suitable basis for further analysis. Similarly, Giannarou and Zervas (2014) noted that values equal to or exceeding 3.0 indicate that the items are relevant and appropriate for inclusion.

This criterion is further supported by Hallowell and Gambatese (2010), who applied the same threshold in a Delphi study focused on construction safety, emphasizing its effectiveness in identifying items with sufficient expert support. Additionally, Sourani and Sohail (2015), in their review of the Delphi method in construction management research, highlighted that the 3.0 mean threshold is commonly used during initial rounds to filter out weakly supported items.

3.3.2 Percentage of agreement. The second criterion applied was the Percentage of Agreement (POA). Combined with the mean calculated in the previous step, these two criteria established the consensus regarding critical SCEs in BIM-based construction projects. The POA is a strong indicator of consensus strength, particularly in Delphi research, where ordinal scales are used to capture expert judgments. By evaluating the dispersion of responses, POA enables a precise characterization of agreement levels, thereby strengthening the methodological rigor.

In this study, POA was calculated as the percentage of respondents who selected either “4 = Agree” or “5 = Strongly Agree” on a 5-point Likert scale. This approach reflects the concentration of agreement among experts and aligns with established Delphi research standards (Von Der Gracht, 2012). This resulted in a value between 0 and 100, where a higher POA value indicates a stronger level of consensus (Von Der Gracht, 2012). A POA approaching 100% indicates near-unanimous agreement, while lover values suggest more dispersed opinions. In alignment with established methodological standards in Delphi research, a consensus threshold of 70% or higher was adopted as the benchmark for sufficient agreement (Kezar and Maxey, 2016). Recent studies in engineering and construction

Table 2. Demographics of the survey respondents

List	Designation and position	Degree of study	Field of experience	Working experience in the construction industry	Working experience in BIM	Organization background	Organization location
1	Virtual design and construction engineer	Master	Building and Construction	1–5 years	1 > year	Contractor	Kuala Lumpur
2	Civil Engineer and Head of the BIM unit	Bachelor	Civil Engineering	>20 years	>20 years	Government	Kuala Lumpur
3	BIM Coordinator	Master	Interior Designer	6–10 years	6–10 years	Contractor	Pahang
4	CREAM SME	PhD	Civil Engineering	>20 years	>20 years	Consultant	Selangor
5	Senior Lecturer	Master	Civil Engineering	11–15 years	6–10 years	Consultant	Johor
6	Senior Lecturer	PhD	Civil Engineering	6–10 years	6–10 years	Academic/ Education	Selangor
7	BIM Director	Master	Quantity Surveying	>20 years	>20 years	Consultant	Kuala Lumpur
8	BIM and Design Engineer	Bachelor	Civil Engineering	1–5 years	1–5 years	Consultant	Kuala Lumpur
9	BIM manager	Diploma/ Certificate	Architecture	>20 years	>20 years	Client/Developer	Selangor
10	Director	Master	Architecture	16–20 years	11–15 years	Consultant	Selangor
11	BIM manager	Bachelor	Architecture	6–10 years	6–10 years	Consultant	Kuala Lumpur
12	BIM Coordinator	Diploma/ Certificate	Building and Construction	11–15 years	11–15 years	Consultant	Putrajaya
13	Senior Graduate Architect	Master	Architecture	1–5 years	1–5 years	Contractor	Putrajaya
14	JPS Consulting Engineers	Bachelor	Civil Engineering	11–15 years	11–15 years	Consultant	Selangor
15	BIM manager	Bachelor	Civil Engineering	6–10 years	6–10 years	Contractor	Selangor
16	General manager	Bachelor	Land Surveying	11–15 years	6–10 years	Client/Developer	Kuala Lumpur

Source(s): Authors’ own work

management continue to support the use of a 75% agreement threshold in Delphi research. For instance, both Jayaweera *et al*. (2025) and Naji *et al*. (2022) applied a 75% agreement benchmark to identify and retain items as a required consensus for their Delphi studies.

3.3.3 Thematic analysis. In addition to quantitative statistical analyses, a thematic analysis was conducted to augment the interpretation of the critical SCEs. The analysis adhered to the six-step methodological framework by Clarke and Braun (2014), which offers a systematic, transparent, and replicable process for qualitative data analysis appropriate for construction project management research. First, comprehensive familiarization with the SCEs was achieved through multiple readings, enabling the recognition of preliminary patterns. Second, initial codes were generated, with each SCE labeled to capture discrete features. Third, the codes were aggregated into potential themes based on conceptual familiarities, facilitating the identification of overarching themes across the SCEs. Fourth, the themes were refined and reviewed to ensure internal homogeneity and external heterogeneity. Fifth, each theme was carefully defined and named to reflect its core meaning. Finally, the themes were synthesized into an integrative narrative that elucidates the underlying structures influencing the prioritization of SCEs.

4. Results

4.1 Round 1 Delphi results

4.1.1 Mean values. In the first round of the Delphi survey, consensus was initially assessed based on the average mean score of expert responses. A total of 18 cost elements achieved a mean value equal to or greater than 3.0 on a 5-point Likert scale, as shown in Table 3. These elements were: BIM coordinator remuneration (3.33), BIM hardware overhead (3.29), BIM model update costs (3.30), BIM modeler remuneration (3.34), BIM consultant remuneration (3.35), BIM software overhead (3.40), QA/QC engineer remuneration (3.20), BIM manager remuneration (3.29), planning/designing cost (3.29), consultant remuneration (3.24), certification fees (3.12), drawing costs (3.00), construction camp costs (3.20), construction manager remuneration (3.10), contingency fees (3.45), conveyance at site costs (3.02), cost engineer remuneration (3.20), and development charges (3.32). These results indicate that experts generally viewed these elements as critical SCEs in BIM-based construction projects and relevant for inclusion in subsequent analysis.

4.1.2 Percentage of agreement. To reach the consensus for phase one, the POA was calculated, with a threshold of 75% or higher. This criterion was applied only to items that had already met the mean threshold. A total of 15 elements fulfilled both criteria, reflecting strong alignment among panel members. These elements included: BIM coordinator remuneration (93.75%), BIM hardware overhead (93.75%), BIM model update costs (87.5%), BIM modeler remuneration (87.5%), BIM consultant remuneration (93.75%), BIM software overhead (93.75%), QA/QC engineer remuneration (75.0%), BIM manager remuneration (93.75%), planning/designing cost (75.0%), consultant remuneration (75.0%), certification fees (87.5%), drawing costs (87.5%), construction camp costs (87.5%), construction manager remuneration (81.25%), and contingency fees (75.0%). These findings indicate a high level of agreement on these soft cost elements, qualifying them for retention in the second round. The results are shown in Table 3.

4.2 Round 2 Delphi survey

The second round of the Delphi survey re-evaluated the 15 critical SCEs identified in Round 1, resulting in a narrowed list of 8 elements.

4.2.1 Mean values. In the second round of the Delphi process, the mean scores were calculated, as shown in Table 3. Out of the 15 elements retained from Round One, a total of 12 elements maintained a mean score equal to or above 3.0, thereby fulfilling the first criterion for consensus. These elements were: BIM coordinator remuneration (3.85), BIM hardware

Table 3. Delphi results

Code	Element	Round one Mean	POA	Round two Mean	POA	Critical
C37	BIM coordinator remuneration	3.33	93.75	3.85	93.75	Yes
C35	BIM hardware overhead	3.29	93.75	4.35	93.75	Yes
C34	BIM model update costs	3.30	87.5	3.35	93.75	Yes
C36	BIM modeler remuneration	3.34	87.5	3.57	93.75	Yes
C33	BIM consultant remuneration	3.35	93.75	3.85	87.5	Yes
C32	BIM software overhead	3.4	93.75	3.92	87.5	Yes
C27	QA/QC engineer remuneration	3.2	75	2.75	87.5	No
C38	BIM manager remuneration	3.29	93.75	3.78	75	Yes
C31	Planning/designing cost	3.29	75	3	75	Yes
C25	Consultant remuneration	3.24	75	3	68.75	No
C10	Certification fees	3.12	87.5	3.22	56.25	No
C29	Drawing costs	3	87.5	3.14	56.25	No
C05	Construction camp costs	3.2	87.5	2.92	56.25	No
C24	Construction manager remuneration	3.1	81.25	3.3	43.75	No
C12	Contingency fees	3.45	75	2.68	43.75	No
C01	Conveyance at site costs	3.02	68.75	–	–	No
C26	Cost engineer remuneration	3.2	68.75	–	–	No
C09	Development charges	3.32	68.75	–	–	No
C14	Documentation fees	2.53	68.75	–	–	No
C16	Chief warehouseman remuneration	1.77	68.75	–	–	No
C30	Energy modeling costs	2.63	62.5	–	–	No
C15	Environmental specialist remuneration	1.77	62.5	–	–	No
C17	Field engineer remuneration	2.24	62.5	–	–	No
C18	General superintendent remuneration	2.29	62.5	–	–	No
C19	Landscape architect remuneration	2.41	62.5	–	–	No
C13	Levy fees	1.65	56.25	–	–	No
C20	Materials engineer remuneration	2	56.25	–	–	No
C02	Mobilization costs	1.1	56.25	–	–	No
C03	Off/on-site logistics costs	1.41	56.25	–	–	No
C06	Roadways at construction site costs	1.82	50	–	–	No
C21	Safety engineer remuneration	2.18	43.75	–	–	No
C28	Schedule engineer remuneration	2.88	43.75	–	–	No
C07	Site utilities costs	1.59	43.75	–	–	No
C22	Soil analyst remuneration	2.12	43.75	–	–	No
C23	Surveyor remuneration	2.35	31.25	–	–	No
C04	Testing materials costs	1.2	31.25	–	–	No

Source(s): Authors' own work

overhead (4.35), BIM model update costs (3.35), BIM modeler remuneration (3.57), BIM consultant remuneration (3.85), BIM software overhead (3.92), BIM manager remuneration (3.78), planning/designing cost (3.00), consultant remuneration (3.00), certification fees (3.22), drawing costs (3.14), and construction manager remuneration (3.30). These results indicate a consistent perception of importance among experts for these cost components in Round Two.

4.2.2 Percentage of agreement. In terms of POA, 8 of the 12 elements that met the mean criteria also achieved a POA value of 75% or higher. That means that eight elements met the consensus of being critical SCEs in BIM-based construction projects. These elements were: BIM coordinator remuneration (93.75%), BIM hardware overhead (93.75%), BIM model update costs (93.75%), BIM modeler remuneration (93.75%), BIM consultant remuneration (87.5%), BIM software overhead (87.5%), BIM manager remuneration (75.0%), and planning/designing cost (75.0%). Although QA/QC engineer remuneration achieved a high

POA of 87.5%, it was excluded due to its mean score falling below 3. The complete results are represented in Table 3.

4.2.3 Thematic analysis. Figure 2 shows the results of the thematic analysis after analyzing the final list of critical SCEs. The analysis categorized the SCEs into two main groups: Technology and Human Resources. Technology includes BIM hardware overhead, BIM software overhead, BIM model update costs, and Planning/designing cost, reflecting the technological investment necessary for successful BIM implementation. Conversely, Human Resources encompasses remuneration for BIM consultants, Modelers, Coordinators, and Managers, highlighting the need for skilled personnel and adequate compensation to drive project success in BIM environments. This thematic categorization enhances the understanding of the critical SCEs.

5. Discussion

5.1 BIM hardware overhead

This cost category encompasses acquiring, maintaining, upgrading, and replacing hardware critical for supporting BIM workflows. Required hardware includes high-performance computers, dedicated servers, enhanced networking systems, and specialized peripherals capable of sustaining the intensive computational loads associated with 3D modeling, clash detection, point cloud crossing, and real-time data exchange. As BIM applications become increasingly sophisticated, the hardware requirements escalate correspondingly, necessitating significant and ongoing financial investments. Consequently, hardware-related costs constitute a substantial proportion of project overheads and can directly influence project feasibility, performance, and long-term organizational BIM capability. This finding is consistent with established cost frameworks, including the New Rules of Measurement (NRM) and International Cost Management Standards (ICMS), which classify technology-related hardware costs as critical elements of project costing across asset lifecycles. Furthermore, Ma (2022) emphasized that although BIM implementation improves cost control, effective implementation is predicated upon substantial investment in hardware that meets the specifications required for BIM workflows. Similarly, Alnaser *et al.* (2024) highlights that although BIM implementation can mitigate cost overruns, the high initial investment for hardware acquisition remains a barrier, particularly for SMEs.

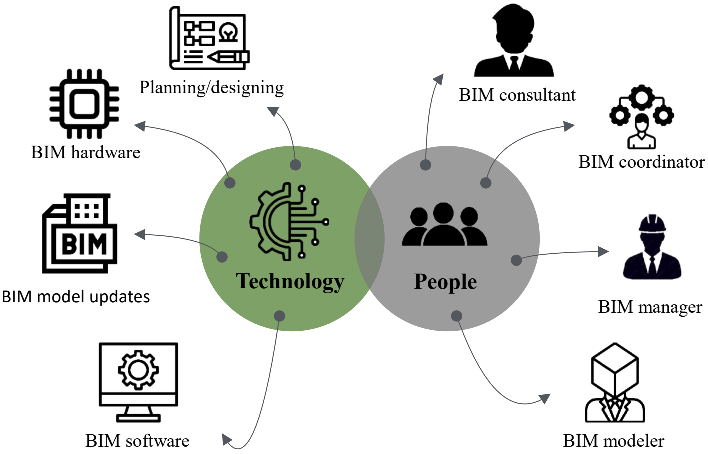

Figure 2. Thematic analysis results. Source: Authors' own work

5.2 BIM consultant remuneration

BIM consultant remuneration includes the fees for specialized BIM professionals, including BIM consultants and auditors, whose expertise is critical to successfully implementing BIM. Although consultant fees often represent a substantial portion of project costs, they are acknowledged as investments that ensure the seamless integration and long-term operationalization of BIM. This finding is consistent with ICMS and NRM, which classify consultancy fees as SCE associated with modern construction projects. Bamgbose *et al.* (2024) noted that high initial costs, including consultant fees, often present barriers to BIM implementation among SMEs. Similarly, Farouk and Rahman (2023) observed that the involvement of BIM specialists improves coordination and data accuracy, though they cautioned that such costs must be managed to safeguard ROI. These findings underscore the imperative to account for BIM consultant remuneration in project costing. Stakeholders can improve project outcomes by ensuring performance expectations are clearly defined, cost control mechanisms are implemented, and BIM implementation is appropriately structured. Proactively addressing this SCE streamlines BIM implementation and contributes to realizing its full value across the project lifecycle.

5.3 BIM modeler remuneration

BIM modelers are critical to the digital transformation of construction projects, serving as architects of 3D models that form the backbone of BIM workflows. Their responsibilities include ensuring compliance with industry standards, conducting clash detection, and collaborating with multidisciplinary teams to develop accurate models. These tasks require a combination of technical expertise in modeling, problem-solving, and an in-depth understanding of BIM protocols. The classification of BIM modeler remuneration as SCE is per NRM and ICMS, as BIM modelers contribute to project planning, design, and coordination rather than directly associated with project execution. This classification underscores the nature of BIM modelers' work, while not directly related to physical construction, is critical for the successful planning, execution, and management of BIM-based construction projects. Tummalapudi *et al.* (2021) noted that the involvement of skilled BIM modelers is critical for minimizing coordination errors and improving the integration of various project disciplines within construction projects. Jalaei and Jrade (2015) further emphasized that BIM can enhance decision-making at the early design stages, although it incurs additional costs related to BIM modelers.

5.4 BIM coordinator remuneration

BIM coordinators are critical to successfully integrating and managing BIM workflows. Their task includes managing BIM execution plans (BEPs), facilitating clash detection, addressing interoperability challenges, and ensuring the quality and consistency of models. These functions are critical for minimizing design conflicts, reducing rework, and optimizing project workflows. Despite the critical nature of their responsibilities, the costs associated with BIM coordinators are often underestimated or neglected during project costing. Recent research underscores the criticality of BIM coordinators in enhancing project performance. For instance, Van Tam *et al.* (2023) highlighted that effective BIM coordination improves project performance by facilitating collaboration, reducing errors, and enhancing decision-making processes. Similarly, Celoza *et al.* (2021) observed that proactive management of BEPs by BIM coordinators is linked to improved cost control. These research findings confirm that investing in skilled BIM coordinators provides tangible benefits. In accordance with NRM and ICMS, BIM coordinator remuneration can be classified as SCE. This classification reflects the critical role of BIM coordinators in ensuring the smooth execution of BIM-based construction projects.

5.5 BIM manager remuneration

As construction projects increasingly implement BIM, BIM managers have become critical. While their responsibilities often overlap with project managers, BIM managers bring specialized knowledge of clash coordination, model-based workflows, and software management, which are increasingly critical in BIM-based construction projects. Recent research highlights the criticality of dedicated BIM managers in enhancing project performance. For example, Zhang *et al.* (2023) emphasized that BIM managers are critical for improving collaboration, reducing errors, and ensuring project efficiency. Similarly, Farouk and Rahman (2023) argue that BIM managers are critical in clarifying cost structures and mitigating risk, especially in complex BIM-based construction projects. These findings underscore that BIM managers are critical and provide long-term benefits that enhance project performance. According to NRM and ICMS, BIM managers are classified as SCEs due to their role in ensuring the delivery of BIM-based construction projects. Properly accounting for these costs during the early stages of project planning is critical for ensuring adequate resource allocation, preventing budget overruns, and addressing coordination challenges effectively.

5.6 BIM model update costs

Identifying BIM model update costs as a critical SCE highlights digital models' dynamic and evolving nature across the project lifecycle. Unlike conventional static drawings, BIM models undergo continuous refinement to accommodate design modifications, site condition changes, and construction sequencing. Core activities, including maintenance of accurate as-built models, issuance of revised coordination drawings, and execution of updated clash detection analysis, necessitate highly specialized technical expertise and sustained interdisciplinary coordination. According to NRM and ICMS, costs associated with documentation revisions, coordination drawing updates, and iterative design modifications are classified as SCE, given their contribution to project execution. Fazeli *et al.* (2021) also demonstrated that continuous model updates increase labor demands and coordination overhead. Their findings also revealed that inadequate update processes lead to model inconsistencies, erode stakeholder confidence, and increase the likelihood of design-related conflicts. Furthermore, Fazeli *et al.* (2021) emphasized that integrating automated BIM model update processes is critical for improving the cost predictability of BIM-based construction projects.

5.7 BIM software overhead

BIM software overhead as a critical SCE reflects the increasing complexity of technology in BIM-based construction projects. This cost category extends beyond initial acquisition, including recurring subscription fees, licensing for multi-platform compatibility, cloud-based coordination environments, and specialized tools (e.g. 4D scheduling and 5D cost estimation). Additionally, costs related to continuous software maintenance, version upgrades, cybersecurity measures, and technical support services are substantial, particularly in projects demanding real-time data exchange, federated model governance, and advanced analytics across multi-organizational platforms. NRM and ICMS classify software costs as SCEs within the broader categorization of IT systems or technology and communications. Fateh and Aziz (2022) highlighted software overhead costs as critical in BIM implementation, particularly when compounded by user training and hardware upgrades. Moreover, prior research advocates that strategic software asset management practices, including centralized licensing models, cloud-optimized deployment strategies, and automated update mechanisms, are critical to optimize cost efficiency. Neglecting BIM software overhead costs during the planning phase can lead to underfunded BIM workflows and operational inefficiencies.

5.8 Planning/designing cost

Planning/designing costs encompass detailed design development, consultant fees, statutory approval processes, and multidisciplinary coordination modeling. These costs ensure accurate project definition, risk mitigation, and regulatory compliance. According to NRM, design-related costs are classified as SCEs, particularly when design liability is contractually shifted to contractors. Similarly, ICMS classifies planning and designing activities as SCEs. In BIM-based construction projects, planning and design costs are more critical than in traditional construction projects due to their expanded scope and intensity. First, BIM requires high levels of design detailing and information modeling early in the project, which increases upfront design costs. Second, BIM-based coordination involves iterative modeling and specialized software usage, driving up planning and designing costs. Third, client and regulatory expectations for detailed digital models before the construction phase further intensifying planning and designing costs. These costs include specialist services and coordinated drawings that are critical but do not directly contribute to physical construction. This distinction reinforces planning and designing costs as a critical SCE in BIM-based construction projects.

5.9 Study implications

5.9.1 Practical implications. The study findings present several practical implications for project managers, construction professionals, and policymakers. The identified critical SCEs can enhance cost planning, resource allocation, and risk control across various project types. For example, identifying planning/designing cost as a critical SCE emphasizes the need for sufficient resource allocation in early-stage design, particularly in renovation works where design changes are frequent. This supports better budgeting and minimizes the risk of cost overruns. The criticality of BIM coordinator and BIM manager remuneration is especially relevant for large-scale infrastructure projects, where these roles are vital for overseeing model integration, clash detection, and maintaining coordination among disciplines. For SMEs and resource-constrained environments, identifying BIM software and hardware overhead as critical SCEs enables more informed decisions on tool selection, investment planning, and training, ensuring infrastructure aligns with available budgets. Public sector projects can benefit from incorporating BIM consultant remuneration and BIM model update costs into procurement and budgeting policies. Doing so supports cost transparency and aligns BIM implementation with realistic expectations, especially in developing countries where financial constraints often challenge adoption. Finally, recognizing BIM modeler remuneration as a critical SCE encourages project teams to allocate an adequate budget for skilled modeling staff, which supports model accuracy and reduces rework during execution.

5.9.2 Theoretical implications. The study findings are valuable for researchers seeking to enhance the ROI of BIM-based construction projects. Future research on BIM hardware overhead should adopt a lifecycle perspective, considering acquisition, maintenance, and upgrades while exploring cloud-based technologies to minimize physical hardware costs. For BIM consultant remuneration, performance-based compensation models aligned with project outcomes and early engagement strategies to reduce rework and delays warrant further investigation. Research on BIM modeler remuneration should assess the impact of model complexity, specialization, and outsourcing versus in-house strategies on cost efficiency. Similarly, research on BIM coordinator and manager remuneration should explore alternative pay structures and the role of coordination tools and remote collaboration in optimizing labor costs. BIM model update costs require the examination of automated update systems, synchronization protocols, and model governance strategies to reduce manual labor. Researchers can investigate platform selection strategies for BIM software overhead that address functional needs, training requirements, licensing efficiency, and system interoperability to prevent cost fragmentation. Planning and designing costs merit further investigation into how BIM influences financial outcomes when design responsibilities shift from consultants to contractors.

5.9.3 Societal implications. From a sustainability perspective, recognizing planning/designing costs and BIM model update costs as critical SCEs highlights the importance of early design accuracy and continuous coordination. These elements reduce material waste and rework during construction, promoting more environmentally responsible practices by preventing resource overuse linked to poor planning or outdated models. In terms of affordability, identifying BIM software and hardware overhead as critical SCEs is particularly relevant for SMEs. These upfront investments often act as barriers to BIM adoption in developing countries. By recognizing their cost impact, industry support programs and funding mechanisms can be better designed to assist SMEs in managing these specific expenditures, improving access to BIM. From a policy perspective, critical SCEs such as BIM consultant remuneration and BIM coordinator/manager roles point to the need for government-backed BIM guidelines that include these roles in procurement and budgeting frameworks. For countries like Malaysia, Indonesia, Egypt, and the Philippines, where BIM implementation is advancing, but cost planning remains inconsistent, these findings can inform more realistic policy tools that align with BIM.

5.10 Limitations and future directions

Although the study's aim was successfully achieved, several limitations should be acknowledged. First, the SLR was confined to articles indexed in Scopus, which may have excluded relevant articles from other databases. Future research can explore other databases. However, snowballing techniques were used to identify additional relevant articles, ensuring a comprehensive review. Second, the data collection is limited to a single country, which could limit the generalizability of the findings to other regions. Despite this, purposive sampling was employed to select knowledgeable experts, ensuring valuable insights were obtained. Third, while the identified critical SCEs are broadly relevant, their significance may vary by project type, scale, and delivery model. Future research could explore these variations to refine cost management strategies across BIM applications. In addition, empirical methodologies to quantify the financial impact of critical SCEs would strengthen the evidence base, enabling predictive analysis and benchmarking. Researchers can also explore how advanced technologies, such as artificial intelligence, can optimize workflows and reduce costs. Comparative research across sectors and regions could yield valuable insights into context-specific practices, contributing to developing more adaptable and cost-efficient BIM implementation frameworks.

6. Conclusion

This study aimed to identify critical SCEs in BIM-based construction projects. To achieve this, an SLR was conducted to identify the SCEs, followed by a two-round Delphi survey to determine the critical SCEs. Thematic analysis was conducted on all the critical SCEs. The results indicate eight critical SCEs that can be grouped into two categories: Technology and Human Resources. Technology includes costs related to BIM hardware, software, model updates, and planning/designing. Human Resources covers the remuneration of BIM consultants, modelers, coordinators, and managers. This study successfully identified the critical SCEs in BIM-based construction projects, providing valuable insights for construction practitioners, project managers, and stakeholders to manage these costs effectively. Theoretical implications indicate that future research could use the identified critical SCEs to develop more accurate cost estimation models and assess their impact on project cost performance. The findings also offer practical directions for improving cost planning in BIM, guiding more strategic budgeting, and helping both private and public sector organizations address critical SCEs. Moreover, the results strengthen the business case for BIM implementation by clarifying often-overlooked cost areas, particularly among SMEs. This finding can help bridge the gap between policy intentions and implementation realities in developing countries where financial constraints remain a barrier.

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