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ABSTRACT

This study aims to investigate challenges in achieving adequate construction readiness for building information modeling (BIM) based building projects, using Malaysia as a case study. To achieve this aim, 20 semi-structured interviews with BIM professionals were conducted using the purposive sampling method. Then, the data were analyzed using thematic analysis. The study results revealed that the challenges can be categorized into two themes: BIM-related challenges and project-related challenges. BIM-related challenges include knowledge, infrastructure, modeling, adoption, and awareness issues. Project-related challenges include funding, communication, team management, cooperation, timeline, coordination, and change order issues. These findings imply that although BIM offers numerous advantages, its implementation introduces specific challenges that differ from those faced in traditional construction projects. These challenges often revolve around technological adoption, data management, changes in project workflows, and team dynamics. Therefore, investigating the specific challenges in BIM-based construction projects is crucial for achieving project success. This study adds to the existing knowledge by providing valuable insights into the challenges faced during the pre-construction phase of BIM-based building projects. The insights can be used to develop strategies for ensuring BIM-based construction projects are ready for the construction phase.

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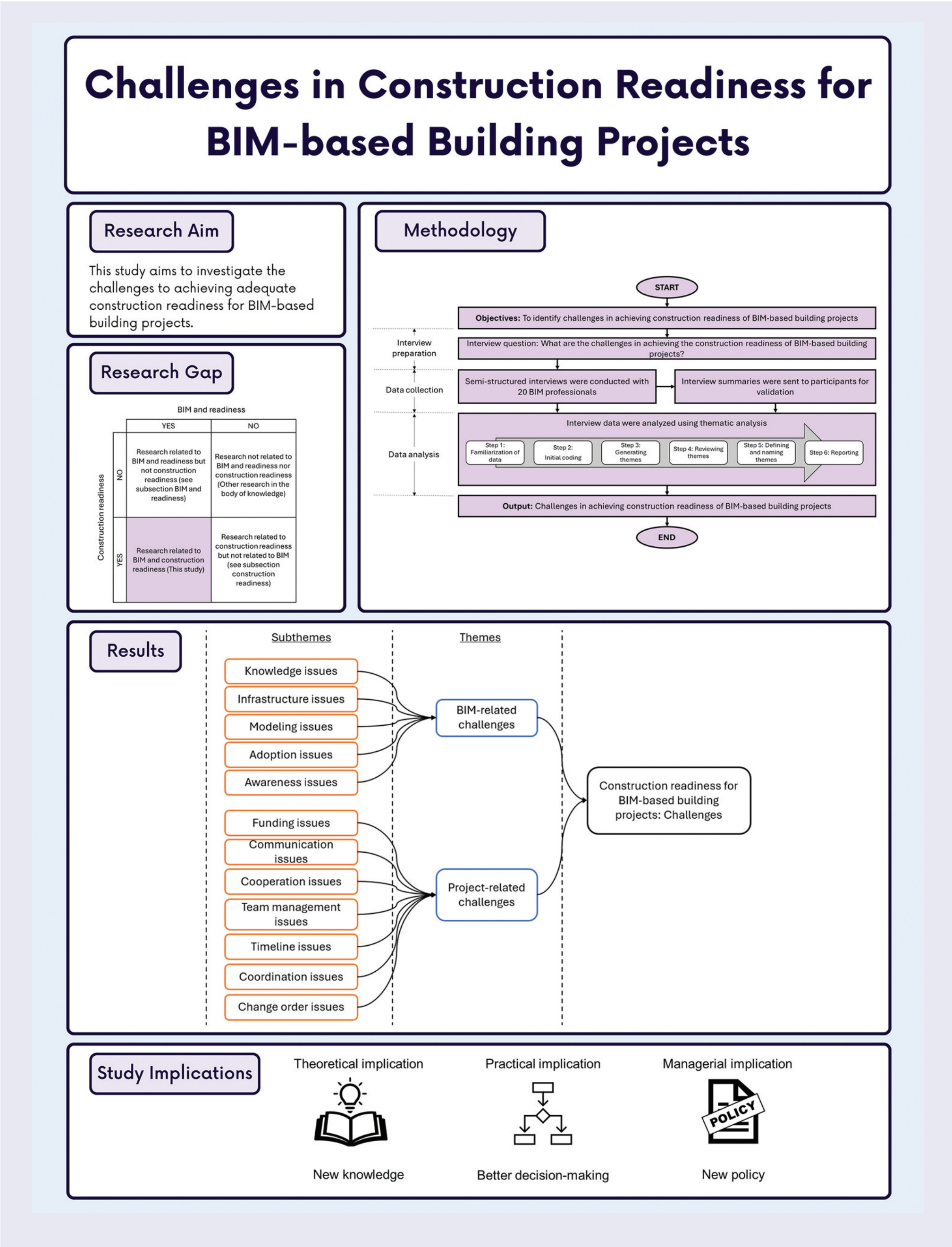

1. Introduction

Building information modeling (BIM) based construction projects may be deemed unsuccessful when they fail to achieve one of the key elements that encompasses time, cost, and quality (Mellado, Lou, and Becerra 2019). For example, failure in BIM-based construction projects in terms of quality often involves inaccurate BIM models. These inaccuracies can have detrimental effects on the operational and maintenance phases of an (Heaton, Parlikad, and Schooling 2019). If the BIM model does not accurately represent the asset's components or systems, it can lead to errors and inefficiencies during maintenance and repairs (Yin et al. 2020). Moreover, cost overruns in BIM-based construction projects may result in project stakeholders being reluctant to implement BIM in future projects. Project stakeholders may perceive BIM as a costly investment that not only requires high initial implementation costs but also can result in additional expenses due to project mismanagement or unforeseen issues (Migilinskas et al. 2013). Additionally, delays in BIM-based construction projects can lead to reluctance among stakeholders to innovate. If BIM implementation does not contribute to streamlining project timelines or improving overall project efficiency, stakeholders may question its value and prefer to stick with traditional construction methods. Therefore, addressing these challenges and ensuring the success of BIM-based construction projects is crucial.

Existing research often focuses on the area of BIM acceptance and BIM implementation (Abubakar and

Table 1. Prior research on project-related and BIM-related challenges.

Scope	Characteristics	Type of projects	Country	Author
Project-related challenges				
Delay	Building projects	No specific type	Saudi	Alshihri et al. (2022)
		Highrise	India	Sanyal (2020)
		Residential	United Arab of Emirates	Namous and Al Battah (2021)
	Infrastructure projects	No specific type	Ethiopia	Melaku Belay et al. (2021)
		Road	Ethiopia	Negesa (2022)
				Ahmed et al. (2023)
		Highway	Pakistan	Zafar et al. (2022)
Cost overrun	Infrastructure projects	No specific type	United Arab of Emirates	Alhammadi and Memon (2020)
			Ethopia	Melaku Belay et al. (2021)
		Tunnel	Pakistan	Ayat et al. (2023)
		Transmission line	Vietnam	Pham et al. (2020)
		Highway	Nigeria	Mahmud et al. (2021)
		Road	United Arab of Emirates	Al Hosani et al. (2020)
	Building projects	No specific type	Saudi Arabia	Alshihri et al. (2022)
Quality management	No specific type		England	Keenan and Rostami (2021)
			Malaysia	Alawag et al. (2023)
			Indonesia	Okifitriana and Latief (2021)
			United States	Lee et al. (2020)
BIM-related challenges				
General challenges	No specific type		United States	Rahman and Ayer (2017)
			Malaysia	Abd Jamil and Fathi (2018)
				Farouk et al. (2023)

Table 2. Summary of prior research on BIM and readiness.

Scope	Description	Level	Characteristics	Authors
Readiness to accept BIM	Willingness and capability of stakeholders to embrace BIM within the construction industry.	Individual	Construction professionals	Adam et al. (2021); Kim et al. (2016b); Zhao et al. (2023); Acquah et al (2018); Britel and Cherkaoui (2020)
			Students	Ahn and Kim (2016).
		Organization	Construction organizations	Hong et al. (2016);
			Higher education institutions	Yusuf et al. (2017)
		National	Russia	Tereshko et al. (2021)
Readiness to implement BIM.	Preparedness of stakeholders to effectively adopt and use BIM in the construction industry.	Individual	Owners and facility managers	Shen et al. (2016)
			Construction professionals	Abubakar and Oyewobi (2019)
			Students	Azhar and Fadzil (2021)
		Organization	Consultant organizations	Abbasianjahromi et al. (2019).
				Juan et al. (2017)
			Quantity surveying organizations	Zhou et al. (2012)
			Construction organizations	Chimhundu (2016); Magalhães et al. (2023); Noor et al. (2022)
			Large design organizations	Phung and Tong (2021).
			SME construction organizations	Arif et al. (2021)
		National	Singapore	Liao et al. (2020)
			Australia	Kim et al. (2016a)

Oyewobi 2019; Zhao et al. 2023). Focusing solely on this area may overlook critical aspects of project improvement, potentially leading to negative impacts. First, if BIM workflows are not improved or optimized, it can lead to inefficiencies in project execution. For instance, rushing through the creation of BIM models without proper checking can result in inaccuracies and inconsistencies. Second, the quality of input data is critical for generating accurate and comprehensive BIM models. If the input data is not detailed or thorough, it can result in incomplete or inaccurate BIM models (Qiu et al. 2021; Volk, Stengel, and Schultmann 2014). Third, BIM outputs play a crucial role in informing decision-making and facilitating project outcomes. For instance, if BIM models lack interoperability or fail to integrate with other smart city technologies, it can impede progress toward achieving smart city initiatives (Costin and Eastman 2019). In conclusion, although focusing on BIM acceptance and implementation is important, it is equally essential to address other aspects of BIM-based projects, such as workflow optimization, input quality enhancement, and output refinement.

One approach to improving the BIM workflow is by assessing the construction readiness of BIM-based projects. In this study, construction readiness refers to the state of preparedness of a construction project to commence and successfully execute construction activities. Research shows that traditional construction projects that are construction-ready experience significant benefits, including reduced schedules, improved productivity, cost savings, less rework, and fewer changes compared to projects that are not construction-ready (CII 2018; Ibrahim et al. 2021). Therefore, to ensure BIM-based projects are construction-ready, investigating the challenges to achieving construction readiness in BIM-based projects is crucial. Understanding these potential challenges enables stakeholders to develop effective strategies to address them. By acknowledging these challenges upfront, stakeholders can implement proactive measures to mitigate risks and minimize their impact on the project. Additionally, awareness of these challenges helps stakeholders set realistic expectations for project timelines, budgets, and outcomes, preventing unrealistic expectations that could lead to disappointment or frustration if challenges arise unexpectedly. In conclusion, there is an urgent need to investigate the challenges to achieving construction readiness in BIM-based construction projects.

Based on the presented background, this study aims to investigate the challenges to achieving adequate construction readiness for BIM-based building projects, using Malaysia as a case study. To achieve this aim, semi-structured interviews with BIM professionals were conducted. The acquired data were analyzed using thematic analysis. Finally, a list of challenges related to the construction readiness of BIM-based building projects was established. This study contributes to an improved understanding of construction readiness, focusing on BIM-based building projects. This study not only contributes to a better understanding of construction readiness in general but also fills the existing knowledge gap by providing specific challenges to achieve construction readiness of BIM-based building projects. The study findings can serve as a valuable resource for stakeholders to address challenges in achieving adequate construction readiness in BIM-based building projects. Moreover, stakeholders can use the identified challenges to develop targeted strategies that address specific issues in achieving adequate construction readiness for BIM-based building projects.

2. Literature review

This section provides a summary of the existing literature pertaining to the study topic. Initially, this study reviewed the current body of knowledge on challenges in construction projects. Furthermore, this study examined prior research on BIM and readiness, as well as on construction readiness.

2.1. Challenges in construction projects

Prior research has extensively examined challenges related to construction projects, particularly in terms of delays, cost overruns, and quality issues. The review focuses on reporting research published since 2020 as the challenges might differ before and after the pandemic. Table 1 shows the summarized prior research on challenges in construction projects that did not specifically focus on BIM. The table shows that research on delays in construction projects have been conducted across different countries and project types, including infrastructure (H. M. Ahmed, Assefa, and Kassa 2023; Melaku Belay et al. 2021; Negesa 2022; Zafar et al. 2022), building (Alshihri, Al-Gahtani, and Almohsen 2022; Namous and Al Battah 2021; Sanyal 2020) projects. Similarly, research on cost overruns have been conducted worldwide, covering a diverse range of project types such as infrastructure (Al Hosani, Dweiri, and Ojiako 2020; Alhammadi and Memon 2020; Ayat et al. 2023; Mahmud, Ogunlana, and Hong 2021; Melaku Belay et al. 2021; Pham et al. 2020), and building (Alshihri, Al-Gahtani, and Almohsen 2022). Most existing research on quality primarily focuses on quality management and has been conducted in countries such as England, Malaysia, the United States, and Indonesia (Alawag et al. 2023; Keenan and Rostami 2021; Lee, Jallan, and Ashuri 2020; Okifitriana and Latief 2021).

Nevertheless, only one research specific to challenges in construction projects that use BIM has been conducted in the post-pandemic context (see Table 1). Farouk et al. (2023) explored trust issues in BIM-based projects. Additionally, upon examining research conducted before the pandemic, only two additional research were identified. Rahman and Ayer (2017) used a mixed-method approach to identify challenges in BIM-based construction projects, emphasizing people and processes as primary causes of issues. Abd Jamil and Fathi (2018) categorized contractual challenges for BIM-based construction projects into six groups, emphasizing factors like interoperability and intellectual property. In summary, numerous research, even after the pandemic, has identified challenges in construction projects. However, prior research that specifically focuses on the challenges in construction projects that use BIM is limited. Therefore, this study aims to fill this gap by focusing on challenges related to BIM-based projects, with a specific emphasis on construction readiness.

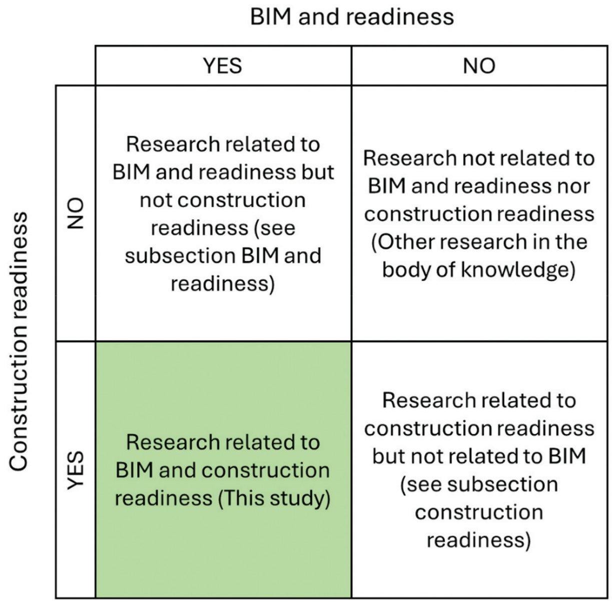

Figure 1. Relationship between this study and prior research on BIM and construction readiness.

2.2. BIM and readiness

Next, Table 2 summarizes prior research on BIM and readiness. The table illustrates that there is many research on BIM and readiness. However, it is also illustrated that prior research mainly focuses on two aspects: readiness to accept BIM and readiness to implement BIM. Readiness to accept BIM involves investigating the willingness of individuals, organizations, and construction industries to embrace BIM. At the individual level, researchers, including Adam et al. (2021), Kim et al. (2016b), Zhao et al. (2023), and Acquah et al. (2018), examined the acceptance level of construction industry professionals on BIM. Furthermore, Ahn and Kim (2016) and Britzel and Cherkaoiu (202) assessed the acceptance level of students (i.e., future construction industry professionals) on BIM. At the organizational level, Hong et al. (2016) identified factors influencing organizational acceptance of construction industry organizations on BIM. Moreover, Yusuf et al. (2017) assessed the readiness of Higher Education Institutions (HEIs) to accept the integration of BIM into existing curricula. Finally, at the national level, Tereshko et al. (2021) determined the readiness levels of Russian regions for BIM implementation.

Similarly, readiness to implement BIM encompasses research conducted at individual, organizational, and national levels. Readiness to implement BIM involves examining preparedness to adopt and use BIM in practice. At the individual level, Shen et al. (2016) evaluated the readiness of project owners and facility managers to implement BIM. Similarly, Abubakar and Oyewobi (2019) assess the readiness of construction professionals to implement BIM. Moving to the organizational level, Abbasianjahromi et al. (2019) and Juan et al. (2017) investigated the readiness of consultant organizations to implement BIM. Zhou et al. (2012) explored the readiness of quantity surveying organizations in the UK to implement BIM. Research, including Chimhundu (2016), Magalhães et al. (2023), and Noor et al. (2022), focused on readiness of construction organizations to implement BIM. Arif et al. (2021) study the readiness of small and medium enterprises (SMEs) in the construction industry to implement BIM. Phung and Tong (2021) developed frameworks to help design organizations build capabilities to implement BIM. At the national level, researchers like Liao et al. (2020) develop models to assess the readiness of the Singaporean construction industry to implement BIM. Similarly, Kim et al. (2016b) investigated the readiness of the Australian construction industry to implement advanced BIM capabilities. In summary, although there is prior research on BIM and readiness, there is limited research in the body of knowledge on BIM and construction readiness.

2.3. Construction readiness

The pressure to start construction early on every project arises because at least one stakeholder stands to benefit from an early commencement. This pressure often leads project teams to initiate the construction phase even when their project may not be fully ready, leading to a premature start in construction. Premature starts refer to situations where construction activities commence before the project is adequately prepared or planned (Griego and Leite 2017). The most common drivers of premature starts in construction are aggressive schedules mandated by the project owner, perceived benefits to the owner from an early start, and the desire for a faster time to market (Griego and Leite 2017). However, such premature starts can lead to out-of-sequence work, cost and schedule overruns, and negative impacts on productivity (Ibrahim et al. 2021). Frequent interruptions, rework of out-of-sequence work, delays, and prolonged request for information (RFI) processing times are some negative consequences of starting a project in a rush (Hanna et al. 2018). To avoid these issues, assessing construction readiness and performing appropriate preconstruction activities are essential. In this study, construction readiness refers to the state of preparedness of a construction project to begin and successfully execute construction activities. Initiating the construction phase before the project is ready can lead to reduced productivity and unsatisfactory performance. Therefore, industry professionals must prioritize assessing the readiness of projects before starting construction to ensure smoother project execution and successful outcomes.

The existing literature on construction readiness is relatively limited, with only a few research have been conducted. Factors distinguishing between construction-ready and construction-not-ready

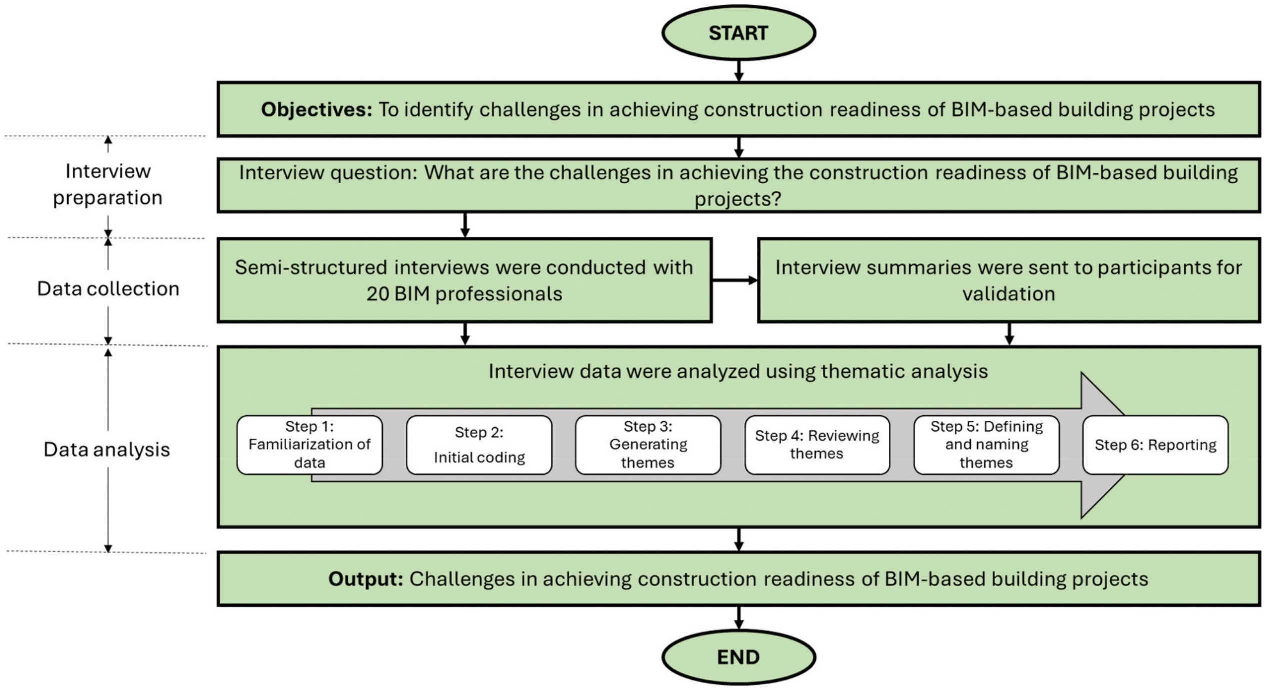

Figure 2. Overview of the research methodology.

projects were identified by Ibrahim et al. (2021), 228 readiness factors were extracted from industry experts, literature on construction readiness, and prevailing industry practices. These factors were categorized into 15 groups, encompassing project teams, engineering, planning, and stakeholder management. Subsequently, a survey was carried out on 80 industrial construction projects, uncovering that construction-ready projects exhibited superior performance in aspects such as cost and schedule. Specifically, construction-ready projects have, on average, a 22% schedule reduction, 29% productivity improvement, 20% cost savings, 7% less rework, and 21% fewer changes relative to not-ready projects. Similarly, Radzi et al. (2022) focused on highway projects and identified key decision criteria for assessing construction readiness. The research analyzed 109 surveys completed by highway industry professionals using techniques such as mean ranking analysis, normalization method, and exploratory factor analysis. The research revealed 18 key decision criteria, which were categorized into four groups: reduced uncertainties, availability of resources, approvals and permits, and adequate traffic management plans. Lastly, Abdul-Rahman et al. (2024) explored decision criteria for assessing the construction readiness of abandoned projects. The research identified 21 decision criteria that are affecting the construction readiness of abandoned housing projects. The decision criteria can be categorized into four underlying constructs: construction site evaluation, management verification, uncertainties mitigation, and document approval. In summary, the current body of knowledge still lacks research on construction readiness in BIM-based construction projects.

2.4. Positioning this study

This subsection summarizes the gaps that exist in the current body of knowledge to establish the rationale for conducting this study. Based on the conducted literature review, it is evident that although a lot of research has been conducted on challenges in construction projects, research focusing on challenges related to BIM-based projects is notably limited. Additionally, research concerning BIM and readiness focuses on BIM acceptance and implementation. Similarly, research on construction readiness has examined readiness in different project contexts, such as industrial projects, highway projects, and abandoned projects (e.g., Abdul-Rahman, Rahman, and Alias 2024; Ibrahim et al. 2021; Radzi et al. 2022).

Figure 1 represents the research gap identified in this study. This gap pertains to the intersection of BIM and construction readiness, where limited research currently exists. In other words, the challenges related to achieving adequate construction readiness for BIM-based building projects remain relatively unexplored. Therefore, this study aims to bridge this research gap by comprehensively investigating and identifying the challenges in achieving adequate construction readiness for BIM-based building projects, using Malaysia as a case study. Thereby closing this gap in the current body of knowledge.

Table 3. Participants' profile.

Participant	Gender	Highest academic qualification	Designation	Experience in the construction industry (years)	Experience in BIM (years)
P1	Male	Masters of Science (Green Architecture)	BIM Coordinator	12	7
P2	Male	Bachelor degree (Civil Engineering)	BIM Coordinator	10	5
P3	Female	Masters of Science (Facilities Planning and Management)	BIM Coordinator	4	3
P4	Male	Bachelor of Mechanical Engineering	BIM Manager	8	8
P5	Male	Bachelor of Building/Property Maintenance	BIM Coordinator	12	6
P6	Male	Masters of Philosophy (Aeronautical)	BIM Manager	11	11
P7	Male	Bachelor of Engineering, Mechanical and Manufacturing Engineering	BIM Coordinator	5	5
P8	Male	Master of Architecture (Architecture)	BIM Coordinator	12	12
P9	Male	Diploma in Mechanical Engineering	Assistant BIM Manager	7	7
P10	Male	Bachelor of Science (Architecture)	BIM Manager	7	7
P11	Male	Diploma in Architecture	BIM Coordinator	10	7
P12	Male	Bachelor of Mechanical Engineering	BIM Manager	6	6
P13	Male	Master of Science (Project Management and Construction)	BIM Technical Specialist	4	4
P14	Male	Diploma in Architecture	BIM Coordinator	2	2
P15	Male	Diploma in Architecture	BIM Coordinator	17	15
P16	Male	Bachelor of Civil Engineering	BIM Coordinator	11	11
P17	Male	Bachelor of Architecture	BIM Manager	15	8
P18	Male	Diploma in Architecture	BIM Coordinator	5	4
P19	Male	Bachelor of Civil Engineering	BIM Coordinator	8	6
P20	Female	Master of Architecture (Architecture)	BIM Coordinator	3	3

3. Methodology

The topic of construction readiness remains relatively underexplored. To investigate this "little-understood phenomenon," this study deployed qualitative research strategy to collect data directly from the field (Neuman 2006; Punch 2005). Qualitative research is best suited for conducting careful explorations of the real-life practices and experiences of individuals involved in the subject matter (Opoku, Ahmed, and Akotia 2016). Figure 2 provides an overview of the methodology employed. The following subsections present the methods employed for collecting and analyzing challenges for construction readiness in BIM-based building projects.

3.1. Interview preparation

This study gathers qualitative data through semi-structured interviews with BIM professionals. This method has been used to identify strategies for improving BIM organizational capabilities in digital construction (Munianday et al. 2022) and addressing

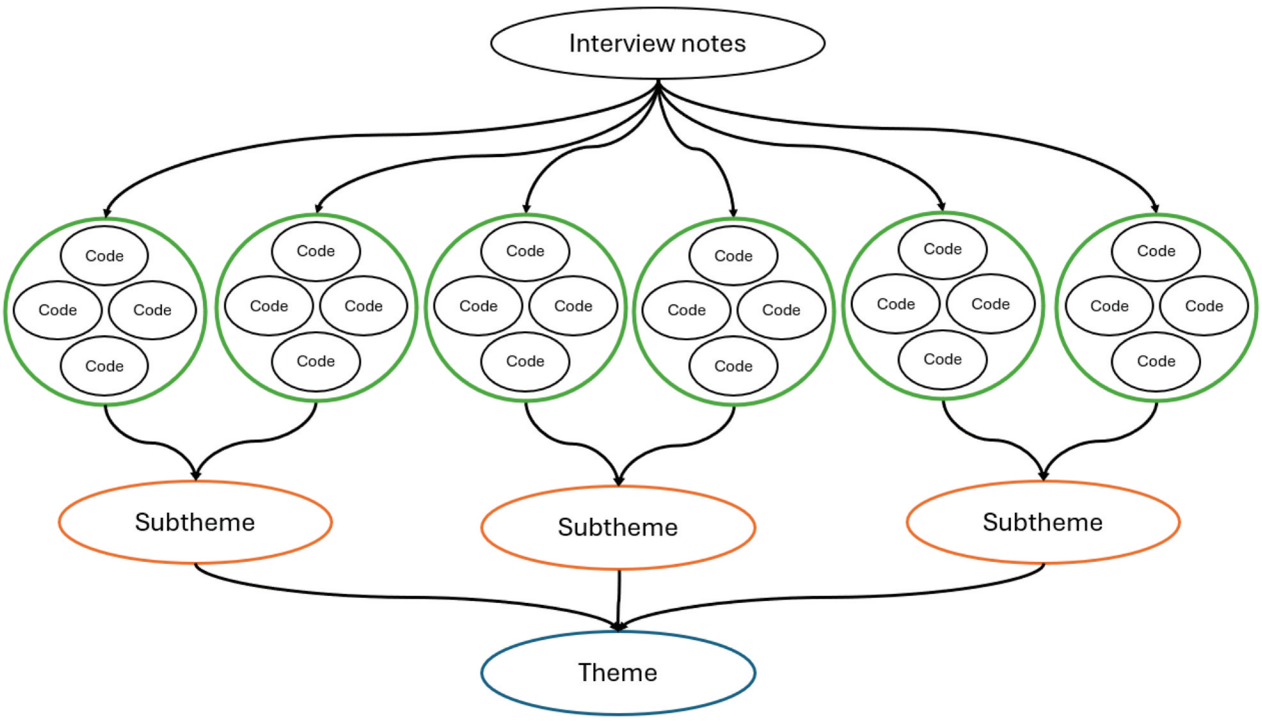

Figure 3. Thematic analysis process.

pandemic impacts on construction projects (Zamani et al. 2022). Semi-structured interviews have been chosen as the method of data collection due to their effectiveness in enabling the interviewer to clarify, understand, and explore the perspectives and experiences of the participants. Interviews serve as a valuable tool for researchers to use existing theories, facilitate the emergence of granular knowledge, and validate existing knowledge using data from the specific context being studied (Creswell 2014).

Building upon the insights from prior literature, a targeted interview question has been carefully crafted: "What are the challenges in achieving the construction readiness of BIM-based building projects?" This question acts as the cornerstone of the interview, guiding the conversation towards a comprehensive exploration of the obstacles encountered in preparing BIM-based projects for the construction phase. An interview protocol was developed to ensure a structured and productive interview process. This protocol acts as a guiding framework, delineating the structure and objectives of the interview session (Papadonikolaki et al. 2022). The interview protocol underscores the voluntary nature of participation, underscoring the autonomy of the interviewees. Additionally, the interview protocol emphasizes the importance of open communication by encouraging interviewees to express any queries or reservations they may have before commencing the interview.

3.2. Data collection

The data collection process involves conducting semi-structured interviews with BIM professionals. BIM professionals are individuals who possess hands-on experience and expertise in using BIM within the construction industry. By selecting BIM professionals as participants, the research ensures that the insights gathered stem from individuals with direct experience and specialized knowledge in BIM. Moreover, prior research have selected BIM professionals as their target population (e.g., Al-Mohammad et al., 2022; Che Ibrahim et al., 2019). Open-ended questions were employed to extract the maximum amount of information from the participants. The sampling method used was purposive, a non-random technique that does not stipulate a specific minimum or maximum number of participants. Instead, it empowers the researcher to gather data by interviewing individuals who can offer insights most pertinent to the study (Etikan, Musa, and Alkassim 2016).

The interview process was initiated with an introduction outlining the motivations behind the interview and the topics to be addressed. Following this, the primary interview question was presented to the participants. Subsequent questions were posed based on the participants' responses. The objective of these follow-up questions was to confirm the correct understanding of the information provided and to attain

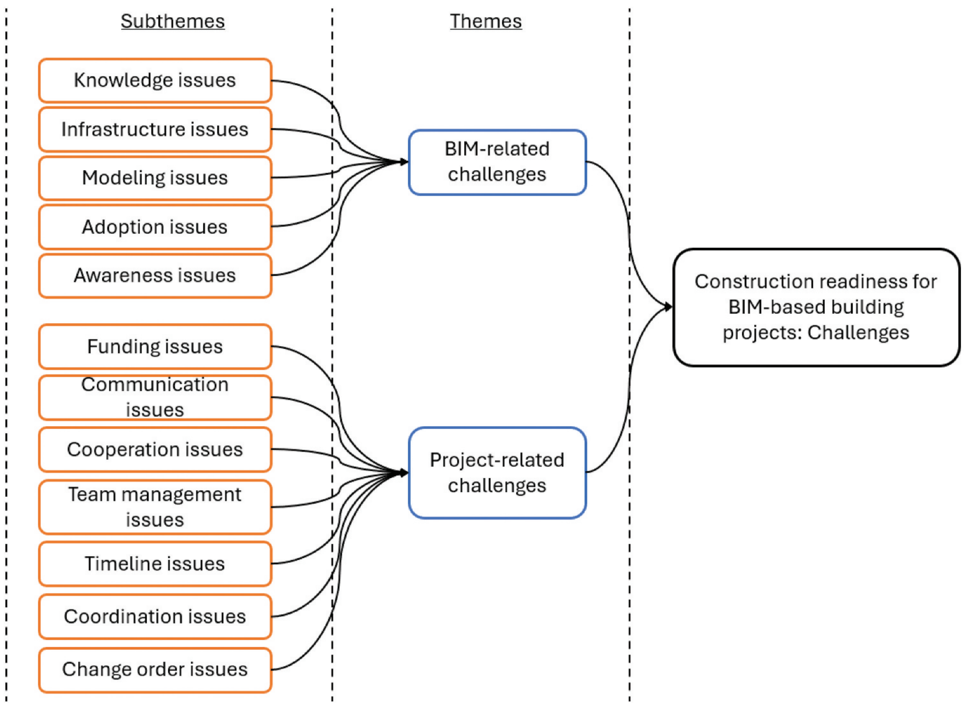

Figure 4. Challenges to achieving adequate construction readiness for BIM-based building construction projects.

Table 4. Themes and subthemes that were identified from the interview data.

Code	Subthemes	Themes	Participants
CH1	Knowledge issues	BIM	P1, P3, P6, P8, P11, P19, P20
CH2	Infrastructure issues	BIM	P1, P3, P6, P7, P10, P11, P15
CH3	Modeling issues	BIM	P1, P2, P12, P13, P14, P16
CH4	Adoption issues	BIM	P4, P7, P8, P11
CH5	Awareness issues	BIM	P14, P16, P19
CH6	Funding issues	PR	P1, P5, P17
CH7	Communication issues	PR	P7, P9, P17, P18
CH8	Team management issues	PR	P4, P5, P15
CH9	Cooperation issues	PR	P14, P17, P18, P20
CH10	Timeline issues	PR	P1, P2, P5
CH11	Coordination issues	PR	P9, P10, P12
CH12	Change order issues	PR	P9, P15

*Notes: BIM = BIM related challenges; PR = Project related challenges.

Table 5. Project-related challenges identified by prior research.

Subthemes	United Kingdom[1]	United States[2]	Hong Kong[3]	New Zealand[4]	Norway[5]	Taiwan[6]
Funding issues	●	●	●	●	●	-
Communication issues	●	●	●	●	●	●
Team management issues	●	●	●	●	●	●
Cooperation issues	●	●	●	●	●	●
Timeline issues	-	●	●	●	-	-
Coordination issues	-	●	●	●	●	●
Change order issues	●	●	●	●	●	●

*Notes: [1] = Ahmed et al. (2002), [2] = Sullivan and Harris (1986), [3] = Kumaraswamy and Chan (1998), [4] = Lessing et al. (2017), [5] = Zidane and Andersen (2018), [6] = Yang and Wei (2010).

Table 6. Supporting statements.

Subthemes	Supporting statements
Knowledge issues	"Modelers do not know the requirements. For example, how to make sure there are no errors in the model and, if there are any errors, how to resolve them." (P11) "Lack of experience in the BIM team can affect the construction process." (P8) "Lack of competent staff." (P6)
Infrastructure issues	"Every party using different software in the project only provides IFC. IFC is hard to coordinate. Issues in the information provided by the consultant because of using different software." (P10) "Software limitation, there is some situation that happened on site that could not be modeled." (P7) "IT items. How the company is willing to spend to implement BIM, software, and machines are expensive. When using old items or devices, they cannot support the software. Also, it could not model correctly; sometimes the computers would hang or freeze." (P15)
Modeling issues	"Even already coordinated BIM model, there are still clashes. When already installed pipe need to call back subcontractor to change due to clashes." (P2) "The model has been coordinated, but there are issues during the installation process due to human errors." (P14) "Modeler uses massing to create a model – lack of detail because massing models represent those that focus on the massing of architecture, not its structural detail, building material, color, or facade." (P13)
Adoption issues	"When the project is not fully BIM, it creates issues. For example, the architect uses BIM, but M&E and C&S do not use BIM." (P8) "Challenges in exposing BIM process flow to team members and stakeholders are reluctant to acknowledge the advantages of BIM." (P7) "No initiative from the client. The client did not push/ask consultants to use BIM." (P8)
Awareness issues	"Stakeholders wanted to start the construction process without checking clashes and checking the model because of the need to comply with the deadline." (P14) "Reluctant of stakeholders in implementing BIM – client, consultant, and contractor." (P16) "People often do not value something if they do not experience the benefit of it. Some professionals do not know the benefits of BIM, so they are reluctant to implement BIM in their projects." (P19)

a deeper understanding of the statements shared. In cases where a direct response or additional information was not forthcoming, the interviewer endeavored to rephrase the question and allowed the participants ample time to respond. Participants were encouraged to continue if they commenced their responses but did not complete them. Subsequently, a summary of each interview was prepared and shared with the participants for validation.

In this study, data saturation was achieved after interviewing the twentieth participant. Data saturation refers to the point in qualitative research where further data collection is unlikely to provide new or additional insights (Faulkner and Trotter 2017). It is a common method used to assess the sufficiency of data sample sizes when no further data points are needed, and the data becomes redundant (Hennink and Kaiser 2022). Thus, the data collected was considered saturated, indicating that additional interviews would not have contributed substantially to new information or insights. Table 3 shows the participants list, which consists of 20 BIM professionals.

3.3. Data analysis

The data analysis involved conducting a thematic analysis to identify the challenges associated with the construction readiness of BIM-based building projects. Thematic analysis was chosen as a suitable approach for making sense of qualitative data (Braun and Clarke 2006). Other construction management research has also used this method to analyze qualitative data (e.g., Radzi et al. 2022; Munianday et al., 2022).

Thematic analysis is exploratory in nature as it aims to discover and understand the rich complexity of the data without imposing preconceived ideas or frameworks. Theme development in thematic analysis is flexible as it can depend on the experience and expertise of the researcher to unveil underlying meanings (Vaismoradi and Snelgrove 2019). The process of thematic analysis followed the six phases described by Braun and Clarke (2006). In the initial phase, the authors familiarized themselves with the interview data by reading and taking notes to capture initial ideas and insights. The second phase involved generating initial codes to encompass potential themes and patterns observed in the data. These codes were continuously reviewed, discussed, and modified as necessary. The authors identified themes based on the initial codes during the third phase. The process involved frequently referring back to the codes and original data. In the fourth phase, the themes were thoroughly reviewed to ensure comprehensive data coverage. The authors refined and defined the themes and cross-referenced them with coded extracts and the entire dataset. Additional themes that emerged were also considered at this stage. In the fifth phase, the authors defined and named the themes, ensuring alignment with independently coded responses. This process involved constant cross-referencing with codes and interview transcriptions to maintain consistency. Finally, in the sixth and final phase, the findings of the analysis were reported, presenting the identified themes for the challenges related to the construction readiness of BIM-based building projects. Figure 3 illustrates the data analysis process of the study.

4. Results and discussion

4.1. Challenges in achieving adequate construction readiness for BIM-based building projects

Figure 4 and Table 4 summarize the themes and subthemes of the challenges identified through analyzing the interview data. This study has identified two main themes of challenges in achieving adequate construction readiness for BIM-based building projects. The first theme is BIM-related challenges, consisting of knowledge, infrastructure, modeling, adoption, and awareness issues. In contrast, the second theme is project-related challenges, consisting of funding, communication, team management, cooperation, timeline, coordination, and change order issues.

Numerous prior research have delved into project-related challenges. To validate this assertion, a literature review has been conducted. Based on Table 5, project-related challenges such as funding, communication, team management, cooperation, timeline, coordination, and change order issues have been extensively discussed in prior research. Such research have been conducted worldwide in different countries, including developed countries such as the United Kingdom (S. M. Ahmed et al. 2002), the United States (Sullivan and Harris 1986), Hong Kong (Kumaraswamy and Chan 1998), New Zealand (Lessing, Thurnell, and Durdyev 2017), Norway (Zidane and Andersen 2018), and Taiwan (Yang and Wei 2010). Thus, this study only focuses on discussing the BIM-related challenges.

4.2. BIM-related challenges

Table 6 presents the supporting statements for the five BIM-related challenges influencing construction readiness in BIM-based building projects. These challenges encompass knowledge issues, infrastructure issues, modeling issues, awareness issues, and adoption issues. Each of the BIM-related challenges is discussed in the following subsections.

4.2.1. Knowledge issues

Knowledge issues refer to challenges related to the understanding and expertise of stakeholders regarding BIM. One of the significant challenges in achieving adequate construction readiness for BIM-based building projects is when workers lack a thorough understanding of BIM and its application in the construction process. A lack of BIM understanding can lead to errors in the BIM model. One barrier to BIM implementation in Australia is a lack of knowledge (Aibinu and Venkatesh 2014). Without proper training and knowledge, workers may overlook clashes, omit critical information, or make incorrect model modifications, leading to potential rework and delays during construction. Thus, organizations should invest in BIM education and training for modelers. Also, regular quality checks and reviews of the BIM models may help identify and rectify any errors before construction begins (Zadeh et al. 2017).

Competent staff refers to individuals with the necessary knowledge, skills, and experience to effectively work with BIM and implement it throughout the project lifecycle. The lack of competent and experienced staff can lead to several issues impacting the construction readiness of BIM-based building projects. Incompetent staff may create BIM models with errors or incomplete information, resulting in clashes, design discrepancies, and coordination issues during construction. Also, workers with little or no experience in BIM may struggle to navigate and operate BIM software efficiently, resulting in slower workflows and potential errors in BIM model creation. Therefore, organizations should invest in training and upskilling staff in BIM processes to address this challenge. Alshorafa and Ergen (2021) highlight the importance of training inexperienced team members in BIM-based projects. Additionally, experienced personnel in BIM play a significant role in reducing the planning and preparation period for BIM processes. Team members already well-versed in BIM can quickly develop BIM Execution Plans (BEPs), create required information tables, and use necessary templates, saving valuable time during project preparation (Alshorafa and Ergen 2021).

4.2.2. Infrastructure issues

Infrastructure issues pertain to challenges and problems related to BIM software and hardware. Issues arising from using different BIM software among consultants can be a significant challenge in achieving adequate construction readiness for BIM-based building projects. Different vendors develop BIM software, which may have unique file formats and data structures. When consultants use different BIM software, it can lead to coordination and data interoperability issues, affecting the overall project preparation and construction process. BIM models created in one software may not be directly compatible with another software, leading to difficulties in sharing and exchanging project information. Also, transferring BIM models between different software formats may lead to data loss or corruption, compromising the reliability of the model. Inefficient data interoperability is one of the critical risk factors for BIM-based building projects in Taiwan (Chien, Wu, and Huang 2014). Thus, organizations need to choose a standardized BIM software platform that all consultants agree to use or ensure that the chosen software applications are interoperable. Besides, BIM software limitations can pose a significant challenge in achieving adequate construction readiness for BIM-based building projects. When some on-site situations cannot be modeled in the software, it can result in issues that may affect the construction process. BIM software may struggle to model highly intricate or irregular geometric shapes correctly in specific architectural designs or structural elements. When these situations arise, it can lead to discrepancies between the BIM model and the actual construction site, potentially causing delays and rework. Accordingly, organizations may conduct frequent site inspections to identify discrepancies between the BIM model and actual site conditions, allowing for timely adjustments.

Another challenge in achieving adequate construction readiness for BIM-based building projects is the use of outdated hardware that may not be able to support the demands of the BIM software fully. BIM requires specialized software and hardware resources to create, manage, and collaborate on BIM models throughout the project lifecycle. When construction teams use old devices or computers with inadequate processing power and memory, it can lead to issues that may affect the efficiency of the BIM modeling process. For example, old devices may struggle to handle the computational requirements of complex BIM modeling tasks, leading to lag and delays in model creation, ultimately resulting in incorrect BIM models. Therefore, construction teams need to invest in updated and capable hardware that can effectively support the requirements of BIM software. Also, regular maintenance and optimization of the devices may help mitigate performance issues and prolong service life.

4.2.3. Modeling issues

Modeling issues refer to challenges and problems that arise during the process of creating digital models for building projects. Despite efforts to coordinate the BIM model and resolve clashes during the pre-construction phase, it is not uncommon for clashes to still be present when construction begins. These clashes can arise due to different reasons, such as human errors, design changes, or incomplete coordination during the earlier stages of the project. Issues occur when clashes are discovered during the construction phase. For example, resolving clashes may require rework and modifications to the construction process, leading to delays in the project schedule. Also, addressing clashes may result in additional labor and materials, leading to increased project costs. Incorrect installations can compromise the safety and integrity of the building, posing potential risks to occupants and construction workers. Therefore, construction teams should implement proactive clash detection and resolution procedures, such as using clash detection software to identify clashes before construction begins and addressing them in the virtual environment. Regular site inspections and checks against the BIM model can also help identify and rectify errors early on, reducing the likelihood of costly rework.

In addition, modelers sometimes use massing models to model projects. Massing models are simplified representations that focus on the overall form and shape of the building, lacking the necessary level of detail required for proper construction and coordination. Lack of detail in massing models can hinder coordination and clash detection during the construction phase. Without a fully detailed model, clashes and conflicts between different building systems may go undetected until the construction phase, leading to rework and delays. Hence, it is essential to ensure that modelers comprehensively understand the project requirements and the level of detail required for construction. Adequate training and clear guidelines on BIM modeling standards can help prevent the use of massing models and encourage the creation of correct BIM models.

4.2.4. Adoption issues

Adoption issues refer to the challenges and obstacles faced during the process of adopting BIM as a new technology or methodology in construction projects. One of the challenges is when the project is not entirely BIM and only a subset of consultants, such as the architect, uses BIM. This can pose a significant challenge in achieving adequate construction readiness for BIM-based building projects. Construction readiness relies on effective collaboration and coordination among all project stakeholders, and partial adoption of BIM can lead to issues that may impact the construction process. For example, if only a subset of consultants is using BIM, clashes may go undetected, leading to errors and rework during construction. Hence, organizations need to establish precise BIM requirements in the project contracts to ensure that all consultants are aligned with the project's BIM implementation goals. Furthermore, the lack of initiative from the client to encourage or mandate the use of BIM by all consultants can be a significant challenge in achieving adequate construction readiness for BIM-based building projects. One of the barriers to BIM use among Swedish medium-sized contractors is the lack of demand from the client (Bosch-Sijtsema et al. 2017). The lack of a client-led push for BIM may result in inconsistent data standards and formats among consultants, making it difficult to integrate and collaborate effectively. Therefore, organizations may provide support and resources for BIM implementation, such as training programs and access to BIM software, which can help consultants transition to BIM more effectively.

4.2.5. Awareness issues

Awareness issues refer to the challenges related to the knowledge and understanding of BIM and its potential benefits among construction project stakeholders. One of the challenges in achieving adequate construction readiness is the pressure from stakeholders to start the construction process without thoroughly checking for clashes and verifying the BIM model due to the urgency to meet project deadlines. In many construction projects, there can be a strong emphasis on completing the project within tight timelines, and stakeholders may prioritize the start of construction over comprehensive BIM model validation. Rushing to begin construction without adequate BIM model checks can lead to several issues during construction. For instance, without proper clash detection and coordination, there is a higher risk of clashes between different building systems. These clashes can cause disruptions, rework, and delays during construction. Therefore, stakeholders and project teams should prioritize and assess construction readiness before starting construction. Also, stakeholders should allocate sufficient time for thorough BIM model validation and coordination before commencing construction.

Moreover, a lack of awareness can lead to reluctance to adopt BIM, hindering the overall implementation of BIM and its potential benefits. Project stakeholders who are not aware of the benefits of BIM may resist adopting new technologies and methodologies, preferring traditional approaches to project delivery. Stakeholders who have been using traditional methods for a long time may feel comfortable with those approaches and may be hesitant to embrace new technologies. To address this challenge, organizations should promote awareness and education about the benefits of BIM among the project stakeholders. Training programs and workshops can familiarize project stakeholders with BIM concepts and associated benefits. Additionally, showcasing successful case studies and real-world examples of BIM-based building projects can demonstrate its positive impact on project outcomes.

5. Conclusion

This study aimed to investigate challenges to achieving construction readiness in BIM-based building projects. The data collection involved conducting interviews with 20 BIM professionals. Thematic analysis was then employed to analyze the collected data. The study findings revealed that the challenges can be categorized into two themes: BIM-related and project-related challenges. Furthermore, as prior research have extensively discussed project-related challenges, this study focused on investigating BIM-related challenges, including knowledge, infrastructure, modeling, adoption, and awareness issues. Understanding these challenges can lead to improved construction readiness practices and ultimately enhance the overall asset life cycle management of BIM-based building projects.

This study contributes to the existing knowledge by shedding light on the challenges in achieving adequate construction readiness for BIM-based building projects. It adds to the body of literature on construction readiness, specifically in the context of BIM-based building projects. These findings imply that although BIM offers numerous advantages, its implementation introduces specific challenges that differ from those faced in traditional construction projects. These challenges often revolve around technological adoption, data management, changes in project workflows, and team dynamics. Therefore, investigating the specific challenges in BIM-based construction projects is crucial for achieving project success. Researchers can use the study findings as a basis for further research and exploration of construction readiness in different settings and industries. For industry professionals, the study findings provide valuable insights into the challenges that can arise in ensuring the construction readiness of BIM-based building projects. Industry professionals can use the study findings to avoid potential pitfalls and obstacles that may occur during preconstruction. By being aware of these challenges, professionals can develop better strategies and approaches to improve construction readiness, leading to more efficient and successful projects. For policymakers, this study highlights the importance of promoting construction readiness practices in the industry. It underscores the need for policies and guidelines that encourage stakeholders to assess project readiness thoroughly before starting construction. By emphasizing the significance of construction readiness, policymakers can help reduce delays, cost overruns, and inefficiencies in construction projects, benefiting the overall economy and the built environment.

Nevertheless, the study findings do have some limitations. First, the study findings may not comprehensively reflect the sociotechnical context of BIM-based building projects in all countries as all participants were from a single country (i.e., Malaysia). As such, caution must be exercised when applying the study findings to other contexts. Future research can opt to repeat the current study design in other countries to allow validation and comparison of findings. Furthermore, the findings cannot be generalized in the same way as quantitative research, as the study involves a qualitative research strategy. Qualitative research focuses on capturing rich, detailed, and in-depth information (i.e., quality data). The qualitative data allows researchers to explore nuances, complexities, and individual perspectives that provide a deeper understanding of the phenomena within specific contexts, which cannot be captured by quantitative research (DiCicco-Bloom and Crabtree 2006). Therefore, qualitative research fits the study aim of investigating the challenges in practice through documenting the experiences of BIM professionals rather than listing or ranking the challenges. However, it is also acknowledged that mixed-method research (i.e., combining qualitative and quantitative methods) could allow data triangulation of the study findings. Therefore, further research may incorporate mixed methods, including expanding the current study findings with quantitative methods.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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