Advanced and Sustainable Technologies
ASET
E-ISSN 2976-2294

Volume 5, No 2, September 2026 [27-39]

Factors Influencing the Integration of Building Information Modeling in Industrialized Building System Projects

Chitrarasan Logendiran[1], Nur Soleha Abdul Rahim[1]* and Fazdliel Aswad Ibrahim[1]

[1]Faculty of Civil Engineering & Technology, Universiti Malaysia Perlis (UniMAP), Kompleks Pusat Pengajian Jejawi 3, 02600 Arau, Perlis, Malaysia.

Received 2 January 2026, Revised 5 February 2026, Accepted 27 February 2026

ABSTRACT

This paper examines the factors influencing the integration of Building Information Modeling (BIM) into Industrialized Building System (IBS) projects to understand current BIM integration practices among construction players, particularly IBS contractors in Wilayah Persekutuan Kuala Lumpur (WPKL) and Selangor. It aims to explore the criteria for technological adaptation and evaluate the level of technological adaptation for BIM-IBS implementation. Consequently, a literature review and instruments to conduct a mixed-methods approach were prepared to collect all required information. Subsequently, a qualitative analysis of the data was conducted. The findings indicate that financial factors consistently drive the most significant adaptation of BIM-IBS technology. The scores show a strong belief that technical abilities and workforce readiness are necessary to align with the demands of BIM-IBS (technical and individual around 4.0 with minimal variability), while financial and organizational perspectives are elevated but erratic (0.57–0.65), underscoring problems with governance and budgeting. In conclusion, experienced professionals are better equipped for and more likely to embrace BIM-IBS adaptation. The results show that the financial and organizational structures possess a strong foundation, both in structure and employee mindset, for effectively embracing new technologies, which aligns with SDG 9 Industry, Innovation, and Infrastructure.

Keywords: Building Information Modeling, Industrialized Building System, Technological Adaptation, Technology Readiness Index.

1. INTRODUCTION

The construction sector has regularly been marked by low productivity, fragmented project execution, budget estimation exceeding, delays, and quality issues relative to other industries. These obstacles have prompted the sector to investigate different building techniques and digital tools to improve efficiency and performance. One approach is the Industrialized Building System (IBS), which focuses on prefabrication, standardization and organized assembly techniques. Previous research has shown that IBS can significantly improve construction quality, shorten project timelines, and enhance sustainability outcomes [1, 2]. Consequently, IBS has attracted greater interest from governments and industry players worldwide as a practical solution to contemporary construction challenges.

The effective execution of IBS requires strong coordination among project collaborators, precise information sharing, and integration across the design, manufacturing, and construction phases. Conventional two-dimensional design techniques and disjointed information streams frequently fall short of meeting the intricate demands of IBS projects. To address these constraints, Building Information Modeling (BIM) has emerged as a revolutionary digital technology that can enable integrated project delivery. BIM enables the development and oversight of smart digital models

*Corresponding author: nursoleha@unimap.edu.my

that assist with collaboration, collision detection, and budget management throughout the building lifecycle [3]. Many studies have demonstrated BIM's capacity to enhance communication, reduce errors, and improve decision-making in construction projects [4, 5].

The combination of BIM and IBS is increasingly recognized as a key strategy for leveraging the strengths of both frameworks. BIM offers a digital platform that facilitates design standardization, prefabrication planning, production oversight, and logistics management, essential elements of IBS projects. Additionally, BIM facilitates the enhancement of prefabricated elements by enabling prompt identification of design issues and better synchronization between digital models and real-world manufacturing workflows. Studies indicate that BIM-supported IBS can notably enhance constructability, decrease rework, and boost project efficiency through improved collaboration [6, 7].

Nonetheless, despite the acknowledged advantages, the use and incorporation of BIM in IBS projects continue to be irregular, especially in developing and emerging construction markets. Current research suggests that the integration of BIM and IBS is influenced by several factors, including financial resources, organizational preparedness, technical systems, workforce skills, sustainability focus, and technological preparedness [8]. Elevated implementation expenses, absent management dedication, inadequate technical expertise, opposition to change, and a lack of trust in new technologies are barriers to successful adaptation. These challenges emphasize that integrating BIM with IBS is not purely a technological concern but also involves organizational and human-centered changes.

Due to these challenges, it is essential to thoroughly investigate the factors affecting BIM integration in IBS projects to aid in efficient decision-making and policy formulation. Understanding these elements will help industry participants pinpoint facilitators and obstacles, enhance technology preparedness, and encourage sustainable execution approaches. This study seeks to explore the financial, organizational, technical, individual, and sustainability factors that affect BIM integration in IBS projects, thereby enhancing both theoretical understanding and practical implementation in the construction sector.

2. LITERATURE REVIEW

2.1 Financial and Organizational Factors Influencing BIM–IBS Integration

Financial and organizational elements are regularly recognized in the literature as key factors influencing BIM implementation in IBS projects. The initial costs of BIM adaptation, such as software purchases, hardware upgrades, training, and workflow modifications, are often seen as a significant obstacle, especially for small- and medium-sized construction companies. Moreover, senior management support is essential for promoting BIM–IBS integration by providing strategic guidance, allocating resources, and fostering an innovative environment.

Organizational readiness, comprising clear workflows, collaborative practices, and supportive policies, has been shown to greatly affect the success of BIM implementation. Researchers highlight that, moving forward, BIM goes beyond a technological shift; it involves an organizational change that necessitates process engineering and collaboration across different functions [9]. Organizations that use integrated management structures and standardized processes achieve better BIM functionality because they require designers, manufacturers, and contractors to work together effectively in IBS projects. Organizations achieve BIM–IBS integration success through their financial stability and organizational development.

The first financial cost of implementing BIM, which includes software purchases, hardware upgrades, employee training, and system upkeep, will require organizations to make a major financial commitment. Organizations with strong financial capacity can better handle expenses while their projects deliver long-term advantages, including reduced rework costs, improved budget management, and increased project execution efficiency. The implementation of BIM-enabled IBS processes becomes unachievable for small and medium-sized enterprises because their financial constraints prevent them from adopting these systems, despite the evidence of productivity increases.

2.2 Technical and Workforce (Individual) Factors Affecting BIM Adaptation in IBS

Two of those factors include technical skills and employee readiness, which are significant for the successful integration of BIM in IBS programs. BIM-informed IBS requires advanced technical infrastructure, including interoperable software platforms, reliable data exchange standards, and accurate modeling protocols. Without effective technology systems in place, the true benefits of BIM for design coordination and prefabrication cannot be realized. Earlier research indicates that technical challenges like software incompatibility, absence of standardized BIM libraries for IBS elements, and inadequate technical assistance can impede successful implementation [10].

The adaptation and actual use of BIM technologies by the workforce are just as important. Human aspects, such as skills, knowledge, experience, human resources, and attitude towards technology, significantly influence the implementation of BIM in IBS projects. Numerous studies indicate that insufficient BIM knowledge and reluctance to adapt among professionals continue to be significant obstacles, especially in conventional construction settings [11, 12]. Education and continuous professional development are key to developing personal skills and confidence with BIM tools. In IBS projects, precision and cooperation are crucial; thus, a skilled and technology-literate workforce is important to support the integration of BIM–IBS.

The successful execution of BIM–IBS integration requires digital infrastructure elements, matching software systems, and standardized data exchange protocols as essential components. The BIM tools must deliver all required IBS features through support for modular coordination, prefabrication detailing, clash detection, and accurate quantity take-offs. The implementation of BIM-based IBS systems faces three main challenges: insufficient technological infrastructure, software systems that cannot work together, and the absence of technical standards.

Workforce (individual) factors are equally critical because BIM depends on users who possess knowledge, skills, and positive attitudes. Professionals with sufficient BIM expertise can utilize BIM capabilities to enhance IBS operations, which involve design coordination, manufacturing integration and construction planning activities

2.3 Sustainability and Technology Readiness in BIM–IBS Integration

Sustainability factors and technology readiness have gained increased attention with respect to the integration of BIM and IBS. IBS is significantly associated with sustainable building practices, as it reduces waste, enhances energy efficiency, and improves building quality. BIM increases these advantages by providing enhanced sustainability analysis, assessments, and resource management in early stages of design [13, 14]. It has been found through research that organizations with a strong sustainability focus will use BIM as a resource to attain organizational goals related to environmental and economic needs.

Technology readiness, commonly assessed with the Technology Readiness Index (TRI), indicates users' enthusiasm, creativity, and uncertainty regarding the implementation of technologies. Studies suggest that elevated optimism and creativity enhance BIM adaptation, whereas unease and uncertainty may hinder implementation [15, 16]. In IBS projects, the preparedness of technology influences stakeholders' views on the practicality and user-friendliness of BIM. Organizations that proactively address user issues through training, support, and change management are more likely to achieve sustainable, enduring BIM–IBS integration. Therefore, sustainability objectives, alongside advanced technology readiness, foster a conducive environment for effective BIM implementation in IBS initiatives.

Organizations with strong sustainability goals are therefore more inclined to BIM–IBS integration as part of their long-term development strategies. Organizations reach technology readiness when they establish their capacity to implement and operate advanced digital technologies. The process of BIM-IBS integration becomes easier when organizations have high technology readiness, including a strong operational technological framework and team members who can drive innovation.

2.4 Technology diffusion

"Technology diffusion" refers to the spread of new technology within a community, organization, or company, and to the exchange of resources, knowledge, and skills to enhance the adaptation and use of the technology. Various factors might influence its diffusion, such as the benefit of the new technology, compatibility with the prevailing technology, availability of resources and support, and the social and cultural context in which the technology is to be implemented. Understanding these factors is essential for successful implementation and moving toward new technology.

The crucial elements that define the rate and extent to which a technology will be diffused include relative advantage, which calculates how preferable the technology is to what already exists; compatibility, which considers how easily the technology can be implemented alongside existing systems and processes; complexity, which denotes how difficult or easier the technology will be to implement and understand; trialability, which refers to how easily or how feasible it will be to pilot and test the technology before full implementation; and observability, which defines how easily others may notice the benefits that the technology may bring.

The spread of technology is enhanced by multiple channels, such as communication networks, social factors, government regulations, and market forces. Understanding these elements and processes is crucial for efficiently encouraging the adoption and successful implementation of new technologies, resulting in greater efficiency and better outcomes across industries.

3. METHODOLOGY

Data were collected through a mixed-methods approach, focusing on qualitative (semi-structured interviews) and quantitative (questionnaires). Semi-structured interviews were conducted online via Google Meet. Prior to conducting an online interview via Google Meet, a set of semi-structured questions was developed to ensure that all relevant information on the criteria for BIM adaptation in construction projects, particularly IBS projects, would be collected. This will help to improve the questionnaire at the final stage using results from the interview. A sample size of five was suitable for this qualitative analysis. Five BIM specialists with professional experience in the construction sector were chosen as participants in this qualitative study. The criteria for participant selection were based on: a) Participation in IBS (precast concrete) construction projects; b) possessing knowledge of BIM; c) having over 5 years of experience in the construction industry; and d) being open to participating in a semi-structured interview. Figure 1 shows the flowchart of the method.

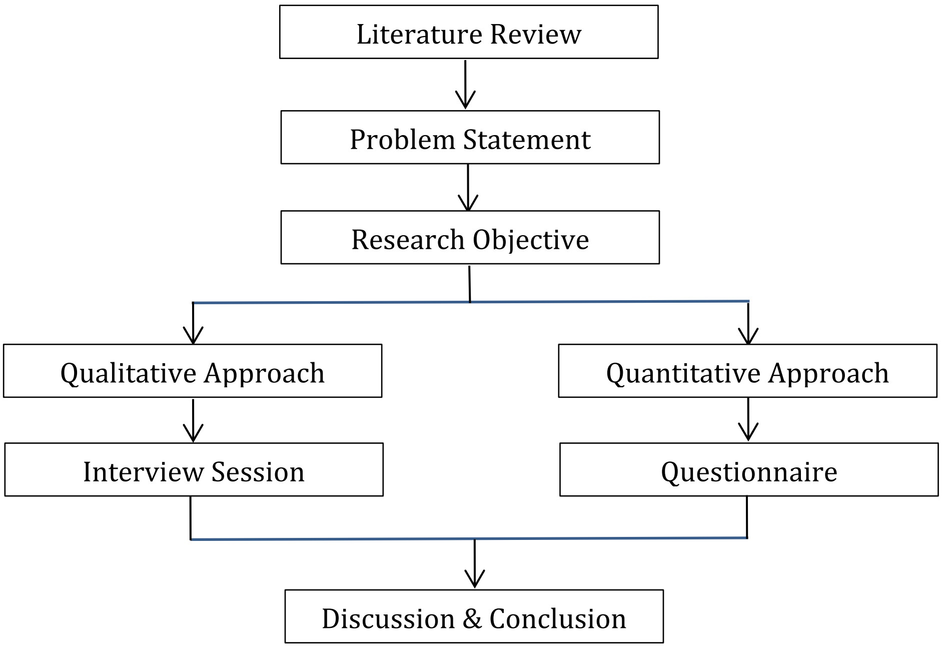

Figure 1: Flowchart of the method.

Additionally, the data collection utilized a questionnaire survey method employing a quantitative approach. The survey was developed following a thorough examination of the current literature concerning BIM implementation in IBS projects. The output from the semi-structured interview was also used to verify the potential criteria and the questionnaire's relevance regarding BIM adaptation. A pilot study was conducted involving responses from 30 participants, which helped to enhance the questions prior to the actual survey. The questionnaire was completed based on insights from the pilot study. The completed questionnaire is made up of three sections: (a) the respondents' general information, (b) research objective 1, and (c) research objective 2. In parts B and C of the questionnaire, the barriers were ranked using a Likert scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree).

Table 1 presents the respondents' demographic profile for the semi-structured interview. The demographic profile includes years of work experience in the construction industry, gender, and higher levels of qualification.

Table 1: Respondents' Demographic Profile (Semi-structured Interview) (n=5).

Demographic Profile	Frequency	Percentage (%)
Years of Working Experience in the Construction Industry		
Less than or equal to 5 years	-	-
5-7 years	1	20
8-9 years	-	-
More than or equal to 10 years	4	80
Gender		
Male	4	80
Female	1	20
Higher level of qualification		
Assistant Engineer	2	40
Senior Engineer	1	20
Professional Engineers	2	40

It was discovered that 80% of the participants were men, whereas 20% were women. Additionally, 20% of the participants had 5-7 years of work experience, whereas the remaining 80% possessed more than or equal to 10 years of work experience.

Likewise, 40% of the respondents were professional engineers, 20% were senior engineers, and the remaining 2 participants were assistant engineers. Demographic examination indicates that they possessed significant professional experience, qualifications, and expertise. Therefore, they were deemed appropriate candidates to be interviewed for this research study.

Table 2: Respondents' Demographic Profile (Questionnaire Survey) (n=98).

Demographic Profile	Frequency	Percentage (%)
Years of Working Experience in the Construction Industry		
Less than or equal to 3 years	14	14.29
4-6 years	31	31.63
7-9 years	27	27.55
More than or equal to 10 years	26	26.53
Gender		
Male	74	75.5
Female	24	24.5
Education		
Certificate	1	1.02
Diploma	14	14.29
Degree	70	71.43
Master	12	12.24
PhD	1	1.02
CIDB Grade		
G4	6	6.12
G5	20	20.41
G6	16	16.33
G7	56	57.14
State of Organization		
WPKL	36	36.73
Selangor	62	63.27

Like Table 2, the profile emphasizes a predominantly male workforce (74) comprising 24 women, demonstrating a solid educational foundation: 70 hold a Degree, 14 a Diploma, 12 a Master's, 1 a Certificate, and 1 a PhD. CIDB qualifications show a majority at G7 (56), with 20 at G5, 16 at G6, and 6 at G4. Experience skews towards mid to senior levels, with 31 individuals in the (4–6 year range), 27 in the (7–9 year range), 26 in the 10 years or more range, and 14 with 3 years or less. Geographically, 62 participants hail from Selangor, while 36 are from WPKL. A total of 98 individuals are participating. Overall, the data suggest a highly skilled, almost senior cohort with strong CIDB qualifications, concentrating in specific domains, while also highlighting opportunities to improve gender diversity, maintain a steady influx of younger talent, and align training and succession plans with regional market dynamics.

3.1 Validity

Validity in research refers to the extent to which a study accurately measures what it intends to measure and whether its findings, conclusions, and interpretations are appropriate and credible. This study applies validation techniques to ensure that the instruments measure the intended variables and that the results accurately represent the target population. Data validity refers to how well the collected data align with established academic research practices [17]. Validity is essential because it prevents researchers from unintentionally measuring variables that are outside the scope of the study [18].

There are four main types of validity: face validity, content validity, criterion validity, and construct validity. Face validity and content validity are primarily qualitative evaluation methods that assess whether the research instrument appears appropriate and adequately covers the study domain. In this study, both face validity and content validity were employed due to their simplicity and effectiveness in preliminary qualitative assessment. These validation processes were conducted through expert evaluation, during which the survey structure, clarity, relevance, and item representativeness were examined. An expert panel typically consists of individuals with specialized knowledge in a particular field who assess whether the instrument effectively measures the intended constructs.

Face validity and content validity serve as the initial steps in ensuring that the questionnaire items align with the variables being measured. To enhance the credibility of the instrument, two university lecturers were selected to review and evaluate the questionnaire, as supported by [19]. These lecturers were chosen due to their research experience and professional expertise in construction, particularly in relation to IBS and BIM. Sufficient time was provided to allow them to thoroughly assess the questionnaire items based on their specialized knowledge.

Based on their feedback, several questions were modified because some items contained ambiguities, errors, or overlapping meanings. Certain terminology was refined to improve clarity and ensure ease of understanding for respondents. Additionally, some existing items were removed as they did not align with the study objectives, and new items were introduced to better capture the intended constructs. The lecturers also provided recommendations regarding the pilot study process, including suggestions on questionnaire distribution and response analysis. Their evaluation confirmed that all components of the theoretical constructs were adequately addressed. All feedback and recommendations were incorporated into the revised questionnaire, which was then used for the pilot study.

3.2 Reliability

Table 3 shows the scale of reliability and Cronbach's alpha coefficient. Cronbach's alpha coefficient is used to determine whether measurement items in a questionnaire maintain internal consistency and assessment reliability.

Table 3: Scale of Reliability and Cronbach's Alpha Coefficient [20].

Cronbach's Alpha Coefficient, α	Level of Reliability
< 0.50	Unacceptable
0.50 – 0.59	Poor
0.60 – 0.69	Questionable
0.70 – 0.79	Acceptable
0.80 – 0.89	Good
≥ 0.90	Excellent

The alpha value needs to be 0.50 or higher, as lower values indicate that the items fail to measure the same construct and require modification or elimination. The range of 0.50 to 0.59 indicates a poor rating because it shows the items do not maintain sufficient consistency. The alpha of 0.60 to 0.69 is questionable, as the scale needs development to improve reliability. The alpha value in the 0.70-0.79 range indicates acceptable reliability, as research purposes require consistent item measurement. The range of 0.80 to 0.89 indicates good reliability, as all items exhibit high internal consistency. The alpha value of 0.90 or higher demonstrates excellent reliability because it shows extreme consistency, which allows researchers to trust that their measurement instruments accurately assess the intended construct.

Table 4 shows five factors, including financial, organizational, technical, individual, and sustainability elements, to evaluate BIM-IBS readiness. The internal consistency of the measurement items was assessed through the application of Cronbach's alpha coefficients. The overall reliability score for all 20 items is 0.844, which falls within the good reliability range, indicating that the instrument is reliable and suitable for further analysis.

Table 4: Reliability Coefficient of the Variables Factors.

Variables	**No. of Original Items**	**Cronbach's Alpha Coefficient**	**Scale**	**Rating**
Financial Factor	4	0.905	≥ 0.90	Excellent
Organization Factor	4	0.718	0.70 – 0.79	Acceptable
Technical Factor	4	0.833	0.80 – 0.89	Good
Individual Factor	4	0.729	0.70 – 0.79	Acceptable
Sustainability Factor	4	0.740	0.70 – 0.79	Acceptable
TOTAL	20	0.844		

The financial factor showed excellent reliability, as indicated to its Cronbach's Alpha of 0.905. The financial readiness assessment, which included both investment capacity and cost factors, demonstrated strong internal consistency, as it successfully measured financial readiness for BIM-IBS implementation.

The organizational factor achieved a Cronbach's Alpha value of 0.718, which falls within the acceptable reliability range. The study found that management support, organizational structure, and organizational policies together defined organizational readiness. The technical factor yielded a Cronbach's Alpha of 0.833, indicating good reliability. The items assessing technical infrastructure, software availability and system integration demonstrate strong consistency and reliably measure the intended technical constructs.

The individual factor obtained a Cronbach's Alpha value of 0.729, which is also considered acceptable reliability. The assessment of workforce capabilities through BIM-IBS requires consistent measurement across all three areas: workforce skills and knowledge, and willingness to adopt the system. The sustainability factor had a Cronbach's Alpha of 0.740, indicating an acceptable level of reliability. The items that assess environmental, economic, and long-term sustainability show consistent measurement performance.

Table 5 shows the reliability assessment results for four technology readiness dimensions: optimism and innovativeness, discomfort and insecurity. The overall Cronbach's Alpha for all 20 items is 0.803, indicating good reliability and confirming that the instrument is suitable for assessing technology readiness among the respondents.

The optimism dimension had a Cronbach's Alpha of 0.825, indicating good reliability. The assessment results demonstrate that the particular items that evaluate positive technology benefits and efficiency improvement create strong internal assessment stability. The innovativeness dimension achieved a Cronbach's Alpha of 0.860, indicating good reliability. The assessment results show that the test items successfully measure how willing test participants are to adopt new technologies, including BIM-IBS.

Table 5: Reliability Coefficient of the Variables of TRI.

Variables	No. of Original Items	Cronbach's Alpha Coefficient	Scale	Rating
Optimism	4	0.825	≥ 0.90	Good
Innovativeness	4	0.860	0.70 – 0.79	Good
Discomfort	4	0.877	0.80 – 0.89	Good
Insecurity	4	0.906	0.70 – 0.79	Excellent
TOTAL	20	0.803		

The discomfort dimension reported a Cronbach's Alpha of 0.877, indicating good test reliability. The items that evaluate user experiences of being overwhelmed or unable to control new technology demonstrate consistent assessment results. The insecurity dimension had a Cronbach's Alpha of 0.906, demonstrating excellent reliability. The assessment results show that the test items evaluating data security problems, system trustworthiness, and technological trust exhibit extremely strong internal assessment stability.

4. RESULTS AND DISCUSSION

4.1 Qualitative

Table 6 elaborates on the broader factors that affect technology adoption for BIM-IBS, highlighting financial, personal, organizational, sustainability-related, and technical factors. According to the overall scores, organizational (33) and financial (37) factors rank highest among all the criteria, followed by sustainability (13) and technical considerations (11). According to this weighting, participants believe that adequate funding, institutional capabilities, and internal management procedures are critical to implementing BIM-IBS. Sustainability, on the other hand, is acknowledged but receives less attention, indicating that stakeholders prioritize immediate practical concerns over long-term environmental objectives. Scholarly works frequently highlight this prioritization, citing organizational structure, leadership support, and financial viability as critical elements impacting moving forward [21].

Table 6: Document analysis of Criteria Technology Adaptation with variables.

	IV (P1)	IV (P2)	IV (P3)	IV (P4)	IV (P5)	Total
RQ1: Criteria Technology Adaptation	20	12	32	21	14	99
Financial	13	3	8	7	6	37
Individual	-	2	2	1	-	5
Organization	5	4	16	8	-	33
Sustainability	-	-	3	4	6	13
Technical	2	3	3	1	2	11
Totals	40	24	64	42	28	198

According to panel-wise contributions, Panels 3 and 4 produce the highest totals (64 and 42), with Panel 3 placing a strong emphasis on organizational and technology adaptation criteria. This suggests that these groups provided more thorough insights into the technological frameworks, internal structures, and workforce capabilities, all of which are essential components of a successful BIM-IBS transformation. While sustainability-related input is clearly present, it seems to be secondary, indicating that respondents may see sustainability benefits as supplementary rather than primary adaptation motivators. Prior to addressing sustainability aspects, construction companies often view BIM adoption through the lens of cost-effectiveness and operational enhancement, according to prior research. Generally, it shows that the adoption of BIM-IBS involves a mix of economic, organizational, and competency-related factors, with financial and organizational preparedness being the most important aspects.

Table 7 shows the ratings given by respondents from five interview panels regarding aspects of the Technology Readiness Index (TRI), which acts as a measure of their technology readiness to interact with BIM-IBS technologies. The components of TRI optimism, innovativeness, insecurity, and discomfort indicate attitudes that can either facilitate or obstruct the adaptation of new digital tools.

Table 7: Document analysis of Technology Readiness Index with variables.

	IV (P1)	IV (P2)	IV (P3)	IV (P4)	IV (P5)	Total
RQ2: Technology Readiness Index	3	3	4	2	2	14
Discomfort	1	1	-	-	1	3
Innovativeness	1	2	1	-	-	4
Insecurity	-	-	2	1	-	3
Optimism	1	1	1	1	1	5
Totals	6	7	8	4	4	29

As mentioned in Table 7, discomfort and insecurity (both 3) are at relatively moderate levels, optimism (5) and inventiveness (4) are the most prominent characteristics among participants. This suggests that most participants have a favorable attitude toward BIM-IBS, along with a sense of potential benefit and interest in digital transformation. These findings align with broader research on technology readiness, which emphasizes how positive attitudes toward technology significantly influence adaptation patterns [22].

When the panel distribution is closely examined, Interview Panel 3 stands out as having the highest overall score (8) among TRI indicators, particularly when it comes to the insecurity category. This suggests that those in Panel 3 are more confident and prepared to use BIM-IBS procedures in their work. The ratings in panels 1, 2, 4, and 5 are moderate but generally balanced, suggesting varying levels of readiness among the larger stakeholder group. These diverse trends align with the literature on BIM, which often emphasizes disparities in preparedness stemming from organizational demands, technological anxieties, or skill gaps. Furthermore, the presence of mild discomfort and insecurity highlights the ongoing learning process associated with BIM-IBS integration [23]. In summary, Table 7 indicates that, despite positive attitudes, the industry still needs targeted training and support systems to improve overall technology preparedness.

Table 8: Mean and Standard Deviation of Variables.

Variables	Mean	Std. Deviation
Financial	4.6148	0.57007
Organization	4.1352	0.65327
Technical	4.0357	0.05317
Individual (Workforce)	4.0587	0.05240
Sustainability	3.9821	0.05028
Optimism	4.2372	0.05528
Innovativeness	4.0944	0.58714
Discomfort	4.0867	0.60507
Insecurity	4.1811	0.62978

The descriptive statistics indicate that all variables had notably high average values, reflecting overall favorable perceptions among participants. The financial aspect has the highest average score (4.6148), indicating that organizations are financially equipped, and, according to [24], this will help them to be inclined to invest in new technologies. The organizational, technical, and individual (workforce) factors exhibit high average values exceeding 4.0, indicating that internal management support, technical infrastructure, and employee competencies are sufficiently strong to facilitate technology adaptation. The small standard deviations for the technical and individual factors indicate that respondents have a high level of consensus on these elements [25].

The sustainability aspect (Table 8), though slightly lower, remains high at 3.9821, indicating good awareness and acceptance of sustainability issues in the construction sector. On the Technology Readiness Index (TRI), high mean scores for optimism and innovativeness indicate that respondents' usual outlook is very positive and that they are ready to adopt new technologies. Simultaneously, high averages for discomfort and insecurity indicate that, while the respondents are very open to the acceptance of technology, some apprehensions and misgivings still linger. The results indicate a high readiness for technology adaptation, supported by financial stability, organizational capacity, technical readiness, and a general positive attitude among employees.

5. CONCLUSION

In conclusion, the synthesis of the three tables has provided an integrated understanding of technology adaptation and readiness in the construction industry. In relation to RQ1 - Criteria for Technology Adaptation, the results show that the most significant criteria are financial and organizational, suggesting that the availability and utilization of financial resources, as well as strong organizational structures, are key determinants of technology adaptation. This result supports the assertion that organizations' commitment and financial readiness are the most significant facilitators of the adoption of advanced construction technologies. Despite the lower indication by the two criteria, technical and sustainable considerations are also significant, pointing to the importance of technical expertise and the increasing need for sustainable construction practices. The lowest result was recorded for the individual criterion, suggesting that although human capability is important, it is considered somewhat less significant than financial and organizational criteria at these stages of adaptation.

Regarding RQ2 (Technology Readiness Index), the findings show that optimism and innovativeness are the dominant dimensions, reflecting generally positive attitudes toward new technologies and a willingness among industry practitioners to explore innovative solutions. Previous research supports this finding by demonstrating that positive beliefs about the benefits of technology and personal innovativeness significantly enhance readiness and adaptation behavior. However, discomfort and insecurity, although less pronounced, suggest that some respondents continue to experience uncertainty, fear of complexity, and perceived risks associated with technological change. Such psychological barriers have been widely reported in construction-related technology studies, particularly in environments undergoing digital transformation.

The descriptive statistics also support these findings, as all factors recorded high average scores, especially the financial, organizational, technical, and personal factors, which clearly indicate a high readiness level for technology adaptation. The high average score recorded under optimism and innovativeness clearly shows positive attitudes towards adapting technology, but the moderate average score of discomfort and insecurity shows that training and change management programs need to be conducted to ensure the success and sustainability of technology adaptation in this industry. The outcome of this analysis clearly shows that technology adaptation in this industry is facilitated by strong financial and technological readiness and positive attitudes among employees. Therefore, to ensure success and sustainability, efforts should focus be addressing technical issues and reducing employee discomfort and insecurity through capacity-building and support mechanisms.

ACKNOWLEDGEMENTS

The author would like to acknowledge support from the Ministry of Higher Education (MoHE) Malaysia through the Fundamental Research Grant Scheme (FRGS), grant number FRGS/1/2023/SSI02/UNIMAP/02/1.

REFERENCES

[1] Blismas, N., Wakefield, R. Drivers, constraints and the future of offsite manufacture in Australia. Construction Innovation, vol 9, issue 1 (2009) pp.72-83. https://doi.org/10.1108/14714170910931552

[2] Pan, W., Gibb, A. G. F., Dainty, A. R. J. Strategies for integrating the use of off-site production technologies in house building. Journal of Construction Engineering and Management, vol 138, issue 11 (2012) pp.1331-1340. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000544

[3] Eastman, C., Teicholz, P., Sacks, R., Liston, K. BIM handbook: A guide to Building Information Modeling for owners, managers, designers, engineers and contractors (2nd ed.). Wiley (2011).

[4] Azhar, S. Building Information Modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering, vol 11, issue 3 (2011) pp.241-252. https://doi.org/10.1061/(ASCE)LM.1943-5630.0000127

[5] Succar, B. Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, vol 18, issue 3 (2009) pp.357-375. https://doi.org/10.1016/j.autcon.2008.10.003

[6] Lu, N., Korman, T. Implementation of building information modeling (BIM) in modular construction. Construction Research Congress (2010) pp.103-112. https://doi.org/10.1061/41109(373)114

[7] Sacks, R., Girolami, M., Lucko, G. BIM and lean construction: Trends and future challenges. Journal of Construction Engineering and Management, vol 144, issue 9 (2018).

[8] Won, J., Lee, G., Dossick, C., Messner, J. Where to focus for successful adoption of BIM within organization. Journal of Construction Engineering and Management, vol 139, issue 11 (2013). https://doi.org/10.1061/(ASCE)CO.1943-7862.0000731

[9] Gu, N., London, K. Understanding and facilitating BIM adoption in the AEC industry. Automation in Construction, vol 19, issue 8 (2010) pp.988-999. https://doi.org/10.1016/j.autcon.2010.09.002

[10] Volk, R., Stengel, J., Schultmann, F. Building Information Modeling (BIM) for existing buildings-Literature review and future needs. Automation in Construction, vol 38 (2014) pp.109-127. https://doi.org/10.1016/j.autcon.2013.10.023

[11] Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., O'Reilly, K. BIM adoption and implementation for architectural practices. Structural Survey, vol 29, issue 1 (2012) pp.7-25. https://doi.org/10.1108/02630801111118377

[12] Cao, D., Li, H., Wang, G., Huang, T., Zhang, W. Linking the motivations and practices of BIM implementation in construction projects. Engineering, Construction and Architectural Management, vol 22, issue 6 (2015) pp.557-578.

[13] Lu, W., Xue, F., Zhao, R., Wu, Z. Exploring the effects of BIM on construction waste reduction. Waste Management, vol 69 (2017) pp.27-38.

[14] Wong, J. K. W., Zhou, J. Enhancing environmental sustainability over building life cycles through green BIM. Automation in Construction, vol 57 (2015) pp.156-165. https://doi.org/10.1016/j.autcon.2015.06.003

[15] Parasuraman, A. Technology Readiness Index (TRI): A multiple-item scale to measure readiness to embrace new technologies. Journal of Service Research, vol 2, issue 4 (2000) pp.307-320. https://doi.org/10.1177/109467050024001
[16] Lin, C., Shih, D. H., Sher, P. J., Wang, Y. L. Consumer adoption of e-service: Integrating technology readiness with the technology acceptance model. Technological Forecasting and Social Change, vol 105 (2016) pp.1-13.
[17] Ghauri, P., Grønhaug, K., Strange, R. Research methods in business studies. Cambridge University Press (2020). https://doi.org/10.1017/9781108762427
[18] Field, A. Discovering statistics using SPSS. Sage Publications Inc. Thousand Oaks, CA (2010).
[19] Sulaiman, N. A., Shaid, N. A. N., Mohd, F. Content validity and reliability of questionnaire on students' perception towards online learning during Covid-19 pandemic. International Journal of Academic Research in Business and Social Sciences, vol 11, issue 7 (2021) pp.519-528. https://doi.org/10.6007/IJARBSS/v11-i7/10234
[20] George, D., Mallery, P. SPSS for Windows step by step: A simple guide and reference. 11.0 update (4th ed.). Boston, MA: Allyn & Bacon (2003).
[21] Månsson, D., Lindahl, G. BIM performance and capability. Delivering Value with BIM, Routledge (2016) pp.46-57.
[22] Parasuraman, A., Colby, C. L. An updated and streamlined Technology Readiness Index: TRI 2.0. Journal of Service Research, vol 18, issue 1 (2015) pp.59-74. https://doi.org/10.1177/1094670514539730
[23] Maskuriy, R., Selamat, A., Maresova, P., Krejcar, O., David, O. O. Industry 4.0 for the construction industry: Review of management perspective. Economies, vol 7, issue 3 (2019) pp.68. https://doi.org/10.3390/economies7030068
[24] Oesterreich, T. D., Teuteberg, F. Understanding the implications of digitization and automation in the construction industry. Computers in Industry, vol 83 (2016) pp.121-139. https://doi.org/10.1016/j.compind.2016.09.006
[25] Oliveira, T., Thomas, M., Baptista, G., Campos, F. Mobile payment adoption: An extended UTAUT2 model. Journal of Business Research, vol 102 (2018) pp.293-302.

Conflict of interest statement: The authors declare no conflict of interest.

Author contributions statement: Conceptualization, L.Chitrarasan, N. S. Abdul Rahim & F. A. Ibrahim; Methodology, L.Chitrarasan & N. S. Abdul Rahim; Software, L.Chitrarasan; Validation, L.Chitrarasan, N. S. Abdul Rahim & F. A. Ibrahim; Formal Analysis, L.Chitrarasan; Investigation, L.Chitrarasan; Resources, N. S. Abdul Rahim; Data Curation, L.Chitrarasan; Writing – Original Draft Preparation, L.Chitrarasan; Writing – Review & Editing, N. S. Abdul Rahim & F. A. Ibrahim; Visualization, L.Chitrarasan; Supervision, N. S. Abdul Rahim & F. A. Ibrahim; Project Administration, N. S. Abdul Rahim; Funding Acquisition, N. S. Abdul Rahim.

Data Availability Statement: All data generated or analyzed during this study are included in this published article.