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A CONCEPTUAL FRAMEWORK PERFORMANCE OF IBS PRACTICES IN CONSTRUCTION PROJECT- A PLS-SEM APPROACH

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Abstract

In Malaysia, the Industrialized Building System, or IBS, was introduced in 1963. However, the level of acceptance and performance of IBS practices among stakeholders remains relatively low compared to developed countries, despite the government's recommendation of 70% IBS usage in government projects and 50% in private projects. This study aims to develop a PLS-SEM model and to evaluate the performance of IBS practice in construction projects to replace conventional method. A quantitative research approach was adopted, where survey data from 120 participants were collected and analysed using Smart PLS software. The environment had the highest content validity (AVE) score of 0.601, according to the model evaluation, which showed adequate convergent validity and significance. Not only that, the analysis also showed that technology, organization, and environment significantly influence by the effectiveness performance of IBS practice in construction projects. The findings of this research provide valuable insights that can contribute to improving IBS practice performance in the construction industry. The performance of IBS can reduce construction waste, minimize workers and contribute significantly among contractors.

Keywords: Relationship, Construction, IBS, Performance, PLS-SEM

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INTRODUCTION

The construction sector in Malaysia plays a crucial role in the country's journey toward becoming a developed nation. The rapid advancement of technology has transformed the industry, promoting sustainable construction practices that significantly impact social activities. Industrialised Building System (IBS) is regarded as a workable option for contemporary building projects (Irwan Hafizy Md Arif et al., 2020). However, the Malaysian construction industry faces significant challenges in meeting the demand and supply of both low-cost and affordable housing while integrating sustainable construction and green technology. Conventional construction methods appear insufficient to address the growing demand, necessitating the adoption of innovative approaches (Abd Rashid et al., 2018).

The construction industry serves as a cornerstone of economic development, and the strategic integration of advanced technologies like Industrialised Building Systems (IBS) stands as a potent catalyst for progress. The government has mandated the use of the Industrialized Building System (IBS) for government projects valued at RM100 million and above, requiring a minimum IBS score of 70%. It has also been established that modular coordination is a norm in building design (MOF, 2020). The government has actively promoted the adoption of the Industrialized Building System (IBS) among contractors through initiatives such as IBS professional training programs and levy exemptions. Despite being a well-established idea, IBS is valued for its ability to decrease dependency on foreign workers, speed up essential building projects, and be applicable in different places.

As a result of the Malaysian construction industry's necessity of moving from traditional building methods to IBS technology in accordance with the Construction 4.0 Strategic Plan 2021–2025, IBS has become one of the possible innovations and commercial ventures (Thomas Tarang et al., 2022). IBS has many benefits for stakeholders, but remains with challenges and limitations because IBS is not fully adopted in construction projects (Abdul Rahim & Latif Qureshi, 2018a). The most significant challenges that hinder the use of IBS are the lack of professionals experienced in IBS systems, high costs, complex regulations in implementing IBS and the difficulty in switching from conventional to IBS systems. Investing in training and capacity building programs to equip construction professionals with the necessary expertise to implement IBS construction practices effectively (Yusop et al., 2024).

IBS practices is defined as a method for thorough integration of system; components are manufactured in a factory and assembled on site (Syafiq Bahrin Bin Samsil et al., 2024). Nowadays, along with the progress of global technology, the perception of the world and the direction of development are changing. This, in turn is increasingly focused on sustainable development. This trend can be seen in every aspect of contemporary live and is linked with the shift

of demands and expectations that society puts on people (Przesmycka & Wieczorek, 2021). The building industry in Malaysia is crucial to make IBS practices work well and can change the construction field from industrial revolution 1.0 to 4.0. To improve IBS practice guidelines is key to boost sustainability and make IBS practice more effective (Riazi et al., 2020).

In Malaysia, prefabrication technology is referred to as the Industrialized Building System (IBS), which is defined as a comprehensive construction process in which most structural components are manufactured either on-site or off-site. These components are then transported to the construction site and assembled with high-precision coordinated connections, ensuring high-quality workmanship and expediting project completion. The benefits of prefabrication have made it possible for housing ministries in a number of nations, including the US, UK, Australia, Singapore, Hong Kong, and Malaysia, to satisfy the rising demand for housing (Nor et al., 2014). IBS tech helps local and global research a save cost, time, and product quality. Construction 4.0 strategic plan for 2020-2025 pushes builders to use new and clever building methods. This move shows the Malaysian government wants to tackle the IBS issue (Zuhairi Abd Hamid; et al., 2020). The practice of IBS is an alternative to overcome challenges in construction projects (Rahim et al., 2020). Conflicts often occur throughout the life cycle of a construction project. This is due to several issues such as project cost overrun, time and product quality (Khahro et al., 2015). IBS emerged as a sustainable approach in design and has been developed as a transformative approach in construction projects. Industrialized Building System is a new age construction technology that imbibes on technicalities and efficiency. Further, it is crucial to increase competitiveness to increase construction productivity in concerning quality, price, safety, and the minimization of construction waste (Al-Awag et al., 2023). In Malaysia, Construction Industry Development Board (CIDB) defines Industrialised Building System (IBS) as a construction technique in which components are manufactured in a controlled environment (either onsite or offsite), then transported, positioned and installed into a structure with less additional onsite works.

IBS contributes many benefits including labour reduction, cleaner and neater sites, easy installation, fast completion, enhancement of quality finished products and flexibility. Construction industries in countries like Singapore and Malaysia have shifted the construction methods from conventional to prefabrication (Abdul Rahim & Latif Qureshi, 2018b).

However, the IBS performance is still far from being satisfactory. Thus, the Malaysian government always supports the implementation of IBS in construction activities as a measure to replace traditional methods. IBS has a critical role in enhancing as well as in the development of the construction sector. Another disadvantage of IBS is lack of conformity to the option of dealing with

the challenge of high demand and supply. Its adoption indirectly aids in the development of the Malaysian economy (Jing Le & Zainal, 2021). Several factors are involved in construction industry in Malaysia include planning, design, conservation and overhaul of various types of constructions developed that comprises civil works and several technologies. However, it must be understood that this still remains derivative of the conventional process. Hence the following is defined as an innovation and sustainable in developing IBS technology for IR 4.0, in cognizance of the current trend in developing IBS technology. In this regard, this paper seeks to find out the relationship between IBS practice and performance of contractors in construction projects. In order to achieve this aim, the study was conducted with the following objectives. The first objective is to evaluate the performance of IBS practices among IBS contractors in construction projects. The research process included defining problem statements, addressing research gaps, and identifying important topics in order to achieve this. As part of this process, a comprehensive literature review was conducted to refine the study's focus, including an analysis of the design and instruments used in previous studies.

The second objective of this study is to develop a Partial Least Squares Structural Equation Modeling (PLS-SEM) model performance IBS practices among IBS contractors in construction projects. Expert validation was carried out as a pre-test of the created instrument in order to accomplish this. A pilot study was conducted to evaluate the questionnaire's validity and reliability preliminary to the main survey. It serves as an initial assessment of the instrument, ensuring that it is robust and suitable for the actual study. Based on the suggested questions, the questionnaire was given to respondents in order to evaluate the study variables' dependability. Data analysis was conducted using SmartPLS version 3.3.3, which was employed to generate the hypothesized relationships. A reliable analytical method for creating and evaluating novel theoretical models is partial least squares structural equation modelling, or PLS-SEM. Additionally, the measurement model and the structural model are the two main assessments that constitute the PLS-SEM model. However, this study focuses exclusively on evaluating the measurement model.

LITERATURE REVIEW

The construction sector, based on the IBS system, is one of the innovations in construction technology today. The Construction Industry Development Board (CIDB) has organised various educational and promotional programmes to promote IBS practices for sustainable development projects and the latest technology prefabrication. This initiative aims to support the performance of IBS practices to replace conventional practices. With IBS practices, contractors can execute projects quickly and eco-friendly construction environment. The construction sector plays a key role in the country's growth. So,

it is crucial that it delivers work that meets customer needs in quality and how sites are run. This means sticking to what's laid out in the specs (Jaffar & Lee, 2020).

The IBS research trend is to measure the performance of IBS practices against the demand and supply of IBS components in construction projects. Global technology and standardisation are changing conventional construction industry practices to IBS systems. This has influenced the environment, land conditions, and skills to meet the demands of various building construction categories towards sustainable technology (Ismail et al., 2018). The transition from conventional building methods to hybrid Industrialised Building Systems (IBS) involves multiple stages. The government's IBS strategy, introduced in 1960, initially gained little traction within the industry. However, significant changes occurred in 2008 when the government mandated the use of IBS in public construction projects. According to statistical analysis from IBS surveys conducted in 2003 and 2008, steel frame systems have become widely used in the construction industry. Malaysia may advance in the transformation of the IBS construction industry by investing more resources in automation and robotics technologies, when the government assumes accountability for this issue. By departing from the size into multiple parts and having strong capabilities in IBS component development, IBS manufacturing is able to transport IBS components more economically (Riazi et al., 2020). The rapid pace of technological modernization today has changed the world's industrial landscape. Industrial Building System (IBS) can be utilized as a pilot project for industrial construction by applying the use of robotic technology in the production of components first, as a move toward the Fourth Industrial Revolution in the construction industry (Irwan Hafizy Md Arif et al., 2020).

The performance of IBS use practices to a system applicable today's demand and supply of IBS. These factors are critical to labor in the production of components, robotics and automation, transportation to enable accomplishment of the work process and the construction of the building needs to be fast. The CIDB Construction Industry 4.0 strategic plan 2020-2025 of the Construction Industry Industrial Development Board, CIDB thus highlighted that construction players should embrace an innovative and creative construction method. Thus, it demonstrates that the Malaysian government has a positive attitude towards solving the More information regarding IBS problem. Problems in practice of construction managerial practices like delays, poor productivity and lack of good practice performance are indicative that IBS projects should seek other management strategies for improving IBS project performance (Rahim et al., 2020). The IBS system is prominent and is considered a contemporary construction technique that emphasizes efficiency and technicality. As part of this it also focuses on the degree of competition to enhance the performance of construction in terms of quality cost and safety as well as the wastage of resources

in the construction sector (Al-Awag et al., 2023). It is because, the Malaysian government often suggest that IBS should be used instead of conventional method in conducting construction activities. Hence, IBS has great value in supporting the development of the construction industry.

Organizational characteristics encompass various aspects of organizations that operate under different circumstances, including work scope, company size, and management approaches in IBS project practices. This perspective emphasizes how important organizational elements serve the purpose of fostering innovation in IBS initiatives, especially in light of Industry 4.0's continuous change (Irwan Hafizy Md Arif et al., 2020). Productivity in an organization is a system of interrelated components that includes continuous process improvement, overall quality management, and the project life cycle. These elements collectively support the industry's ability to enhance innovation productivity and meet the evolving market demands in line with current trends (Qin et al., 2020). As a result, this study highlights three organizational elements that are crucial to the success of IBS projects which are internal stakeholders, organizational resources, and organizational creativity.

The environment is defined as an attribute that enhances IBS performance practices in the construction industry. IBS systems have many benefits in the environment such as the generation of construction waste, the use of recycled or renewable materials (Yunus et al., 2019). In this context, "environmental" refers to external factors that affect a business's capacity to apply sustainable innovation in building projects. It shows how organizations react to opinions about procedures, difficulties, and business concerns, leading to logical conclusions based on past performance and societal justification. This study is classified into three parts: government policy, IBS popularity in the construction industry, and competition from other companies. The construction industry's embrace of information technology is significantly supported by government policies. The Construction Industry Development Board (CIDB) has established policies mandating the government's role in ensuring IBS project performance. For instance, the government requires that commercial projects accomplish at least 50% IBS implementation, while all public projects must reach at least 70% (Yusof et al., 2024). The government's role is also essential in enforcing regulations that drive industry stakeholders to take proactive and innovative measures for sustainable project delivery. These efforts serve as a source of productivity which aligning with the goals of Industry 4.0 transformation (Roslan, 2022).

The government has put in place a policy where each project is required to achieve a minimum level of 70% IBS use and 50% IBS use in private projects (Yusof et al., 2024). The role of the government is very important to see the extent to which regulations are required to ensure that each party involved in the IBS project takes active and innovative steps towards sustainable delivery and

productivity drivers towards industrial revolution 4.0. (Roslan, 2022). The conceptual model demonstrates the direction of the research investigation by demonstrating the direct and direct relationship between the research variables. The research model depicted in figure 1 embodies technology, organizations that have IBS practice performance in construction projects. The model also includes three projected hypotheses with arrows indicating the hypothesized relationships.

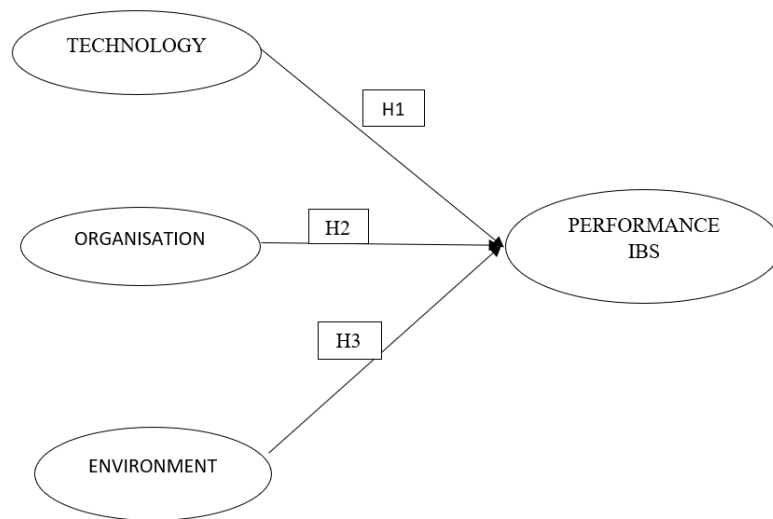


Figure 1: Conceptual Framework

H1: There is a significant relationship between technology utilisation and the construction period on-site, as high costs are required for ordering formwork, machinery, and transportation for the installation of IBS components. Not only that, many contractors also find it difficult to switch from traditional methods to IBS, which is a significant issue in IBS practice.

H2: There is a significant relationship between an organisation's utilisation of resources such as knowledge and skills in IBS to enhance productivity, compete with developed countries, and gain internal support through social factors.

H3: There is a significant relationship between the environment, government policies, popularity, and competition from various conditions. The environment, governmental regulations, public opinion, and competition from different circumstances are all significantly correlated. One of the major environmental advantages of IBS methods is reducing construction waste. Additionally, government regulations also play a role to the development of information technology in the building sector.

RESEARCH METHODOLOGY

This study uses a quantitative approach through a questionnaire survey. The instrument used in the study is a questionnaire. The instruments used must meet the criteria of reliability and validity (Sanchez-Franco & Roldán, 2010). An expert panel was interviewed to validate the developed instrument, providing evidence of its reliability and content validity. The insights and contributions of these experts played a crucial role in refining the instrument before distributing the questionnaire to respondents. The validity of the instrument was further strengthened by conducting a pilot test to find any potential flaws and improve reliability. The expert panel comprised individuals with extensive experience in Industrialized Building Systems (IBS), ensuring the credibility of the validation process. A total of nine (9) expert panels were identified for instrument content validation. The panel of experts identified are experts in the field of civil engineering from various organisations, namely two (2) from the Public Works Department (JKR), three (3) from CIDB, and four (4) from private companies. The validation of the questionnaire, the number of responded regarded as sufficient for the pilot test is between 20 and 40. Hence 30 people responded to the questionnaire out of which 10 people had more than ten (10) years of experience in the field of IBS.

The data that was gathered was then examined through a reliability analysis test. This test supports that one has construct validity of the used instrument as well as the range within which Cronbach's alpha value should be more than 0.6 (Hair et al., 2019). As a result of the findings obtained in this study, all the reliability of the pilot test exceeded 0.600 as shown in table 1. This is evident in the instrument being the survey administered real with more confident respondents. This study employed a survey method, with five-point Likert scale as a tool. The major aim of the survey was to identify the participant of the respondents whereas the second part was intended to identify the performances of IBS for government construction projects.

Table 1: Reliability test for pilot test

Construct	Item	Alpha Cronbach
Time	3	0.642
Cost	4	0.810
Challenge	10	0.778
Resources	5	0.839
Productivity	6	0.889
Social cultural factors	8	0.918
Government Policy	6	0.935
Popularity	3	0.942
Clean environment	5	0.952

The survey was distributed to IBS contractors utilizing precast concrete in government construction projects. Selangor was chosen as the primary focus area because, compared to other states, it has the highest number of CIDB-registered contractors. According to CIDB statistics as of 2022, the state of Selangor registered a diverse range of IBS contractors across multiple system categories, including 602 contractors specializing in precast concrete systems, 2,218 in steel frame systems, 96 in formwork systems, and 42 in timber frame systems. Therefore, this study specifically focuses on the implementation of precast concrete systems within the state of Selangor. Moreover, personnel from the Construction Industry Development Board (CIDB) were also interviewed to provide a more comprehensive understanding and in-depth analysis of IBS performance among contractors using precast concrete in government construction projects.

120 survey questionnaires were distributed to contractors engaged in IBS projects via an email attachment or Google Forms (online self-administered web-based questionnaires). The completed questionnaires or forms were returned to us via the same method or submit to an email. The respondents involved in this research are the respondents are experienced contractors in IBS projects in Malaysia. This study focuses on contractors involving precast concrete in IBS projects in Selangor. From 120 questionnaires distributed, only 114 responses were received. Next, Structural Equation Modelling (SEM) used for analysis. Structured equation modelling (SEM) is a second-generation statistical analytic technique for investigating the interrelationships among various variables in a model (Zhang et al., 2020). The PLS-SEM technique is widely used in model development by researchers in various fields approach to investigate the factors influencing social network acceptance. In this research, the analysis used a single approach suggested (Hair et al., 2014) which focus on the assessment of measurement model only. Generally, the objective for evaluating the research model is to examine whether both measurement and structural meet the underlying quality criteria for empirical work (Hair et al., 2014).

RESULTS AND DISCUSSION

With the help of the questionnaire, 114 questionnaire forms were collected which were used for statistical analysis. The respondents participating in the survey had several level of academics background and experience level as summarized in Table 2.

Table 2: Characteristics of the respondents

		Frequency	Percent	Cumulative Percentage
Company Grade	G1	5	4.3%	4.3%
	G2	5	4.3%	8.6%
	G3	8	7.0%	15.6%
	G4	2	1.7%	17.3%
	G5	8	7.0%	24.3%
	G6	10	8.7%	33.0%
	G7	76	67%	100%
Total	114	114	100%	
Experience	1-5 years	51	44.7%	44.7%
	6-10 years	26	23.0%	67.7%
	11-15 years	15	13.1%	80.8%
	>15 years	22	19.2%	100%
Total	114	114	100%	

PLS-SEM model analysis is a popular among researchers to evaluate measurement model for validating the relationships between reliability refers to degree to which a scale delivers consistent and stable (Hair et al., 2014). The analysis of the reliability and validity of the model measure was carried out through partial least squares-structural equation modelling (PLS-SEM) analysis by using Smart-PLS software application (Fatimah Hashim et al., 2023). This evaluation is crucial to ensure the validity of the measurement model before proceeding with any model checking or hypothesis testing. Thus, for this study, one of the expressed aims has to be the proof of construct validity which has to be confirmed by checking whether the measurement constructs exhibit a consistent pattern or not. Information about the construct validity can be derived from – Convergent – “Cronbach Alpha” and factor loadings Discriminant validity – AVE and last but not least measurement reliability.

PLS SEM Model Analysis: Internal Consistency Reliability and convergent validity

Cronbach’s alpha, rho_A and composite reliability are secondary indicators of reliability. Mainly, the independent variables used in earlier research include most of the time CA, rho_A, and CR. CA is most often used when applying measurements to examine the internal consistency of the data collected. It gives a measure of reliability from the observed measures or items of an instrument or an assessment test. Though, theoretically, it is believed that CR provides a better measurement in internal consistency since when PLS algorithm is employed, a different standardisation is used of its items; however, CA is most often utilised for defining internal consistency reliability. A satisfactory value of Cronbach's alpha, CR, and rho_A is above 0.70. Nevertheless, a value of 0.60 and above is accepted because the value is close to 0.70 (Hair et al., 2019).

Table 3: Internal consistency reliability

Criteria	Alfa Cronbach	Rho A	Composit Reliability
Organization	0.663	0.696	0.795
Environment	0.780	0.801	0.857
Performance IBS	0.611	0.621	0.776
Technology	0.710	0.723	0.811

Convergent Validity

The level of construct convergence was evaluated using ‘Average Variance Extracted (AVE)’ to examine the convergent validity of the measurement model. AVE is the arithmetic mean of all the individual indicator variances shown as a proportion of the overall variability in the construct (Salhi & Messaoudi, 2021). Convergent validity then refers to the closeness of each item that a construct has with the items that is measuring another construct. Regarding the method of analysing the convergent validity, according to (Sarstedt et al., 2022), it is to be averaged on the measure that is the value the variance extracted which a higher substantive aspect of the latent construct implies the greater degree of the explained variances of items. Therefore, it must explain in excess of 50% the AVE, ($AVE \geq 0.500$) in order to obtain a reasonable level of convergent validity, the defined item. During the research, the first enjoy of the PLS-Algorithm has indicated that all the construct’s achieved an AVE value more than 0.50, as is evident in Table 4, emphasizing that the value of each research construct’s AVE is between 0.465 and 0.601 is higher than the standard value that is prescribed, according to which external loading should be at least 0.600 and the better if it equals 0.70. Other literature suggests that items with an external load between 0.400 and 0.700 can be maintained (accepted) if the CR and AVE values are higher than the threshold (0.70 for CR and 0.5 for AVE) (Hair et al., 2019). The developed model is depicted graphically in Figure 2.

Table 4: Convergent Validity

Criteria	AVE
Organization	0.498
Environment	0.601
Performance IBS	0.467
Technology	0.465

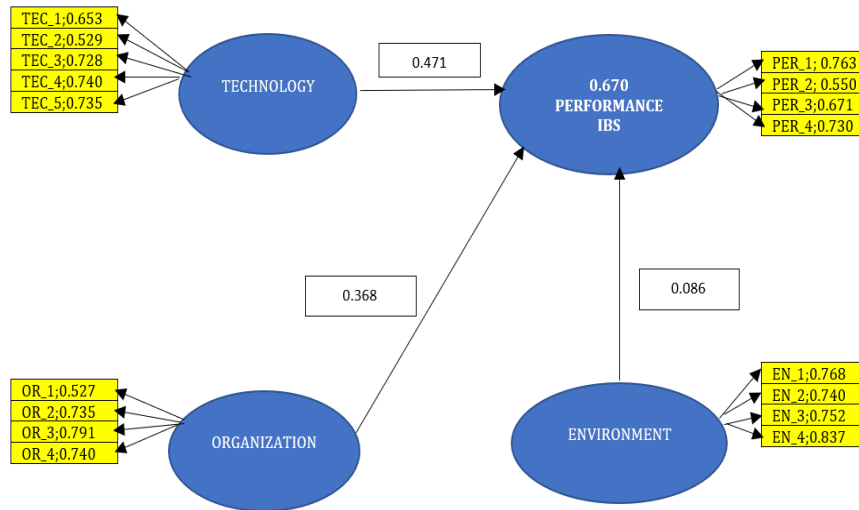


Figure 2: Results of Measurement Model

PLS SEM Model Analysis: Discriminant validity

Discriminant Validity

Discriminant validity on the other hand refers to the level of separation between the various dimensions of a research concept. It indicates the level of dissimilarity between one construct and the others within any given model. In Smart PLS 3.0, discriminant validity can be assessed using three main criteria: the Cross Loading Criterion, Fornell-Larcker Criterion, and the Heterotrait-Monotrait Ratio (HTMT). The cross-loading criterion for discriminant validity is met if the items loading is higher within their own constructs than on any other construct. Table 5 demonstrates that all indicators are appropriately loaded onto their respective constructs, confirming discriminant validity among all constructs. The results showed no significant issues with high cross-loadings between items.

Table 5: Cross Loading Result

Construct	Technology	Organization	Environment	Performance IBS
PER 1	0.474	0.361	0.763	0.613
PER 2	0.323	0.432	0.550	0.558
PER 3	0.556	0.412	0.671	0.396
PER 4	0.581	0.531	0.730	0.474
EN 1	0.379	0.768	0.454	0.528
EN 2	0.508	0.740	0.474	0.478
EN 3	0.527	0.752	0.386	0.430
EN 4	0.644	0.837	0.611	0.537
OR 1	0.527	0.264	0.329	0.236

Construct	Technology	Organization	Environment	Performance IBS
OR 2	0.375	0.518	0.447	0.436
OR 3	0.791	0.547	0.613	0.506
OR 4	0.740	0.517	0.562	0.480
TEC 1	0.437	0.449	0.569	0.653
TEC 2	0.370	0.417	0.343	0.529
TEC 3	0.391	0.428	0.486	0.728
TEC 4	0.313	0.439	0.510	0.740
TEC 5	0.539	0.454	0.594	0.735

Fornell-Larcker criterion. This criterion states that if need to demonstrate sufficient discriminant validity, the square root of the AVE for a particular construct must be higher than its correlation with any other construct (Hair et al., 2014). The results presented in Table 6 indicate that all constructs meet this requirement, demonstrating sufficient discriminant validity. This finding demonstrates the sufficient validity of the main constructs associated with IBS practice performance, such as technology, organization, and environment.

Table 6: Fornell-Larcker Criterion

	Organization	Environment	Performance IBS	Technology
Organization	0.706			
Environment	0.673	0.775		
Performance IBS	0.712	0.635	0.683	
Technology	0.608	0.640	0.750	0.682

The Heterotrait-Monotrait (HTMT) ratio is used to assess the correlation between constructs to determine discriminant validity. According to Hair et al. (2014), the value of HTMT value shows less than 1 which means the ration of correlations within the constructs to correlation between the construct is acceptable.

Table 7: HTMT Result

	Organization	Environment	Performance IBS	Technology
Organization				
Environment	0.894			
Performance IBS	1.086	0.904		
Technology	0.850	0.861	1.118	

The HTMT value of the environmental construct to the organizational construct is 0.894. The HTMT value of the IBS performance construct against the organizational construct is 1.086, while the HTMT value of the IBS performance construct of the environment construct is 0.904. The HTMT value of the technology construct to the organization is 0.850. Next, the HTMT value of the technology construct to the environment construct is 0.861 and the HTMT value of technology to the IBS performance construct is 1.118. Therefore, it can be concluded that the construct measured is acceptable excepted HTMT value of the IBS performance construct against the organizational and HTMT value of technology to the IBS performance.

CONCLUSION

This paper reports on various factors that influence the effectiveness of IBS practices in construction projects to replace conventional practices. This study was conducted by developing the relationship between factors influencing the practices of IBS contractors. Data collection was carried out through questionnaire survey where 114 data samples were collection and analyzed with SmartPLS software. The evaluation model developed to study the effectiveness of IBS practices among contractors in construction projects revealed that technological factors such as time, cost and challenges while organizational factors such as resources, productivity, social and environmental factors such as government policy, popularity and orderliness. This study will help contractors understand effective practices in IBS construction projects to replace conventional practices.

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ETHICAL STATEMENT

This study obtained informed consent from all participants and was conducted in strict confidence. The authors declare that there are no conflicts of interest and confirm that the study is original, unpublished and not under consideration elsewhere.

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