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Evaluating the Effectiveness of Industrialized Building Systems (IBS) in Reducing Construction Waste in Kuching, Sarawak

Mohamad Zain Hashim[1,2], Florence Simba Anak Charles Muntath, Idris Othman[2], Muriatul Khusmah Musa[1]

[1]Civil Engineering Studies, College of Engineering, Universiti Teknologi MARA Cawangan Pulau Pinang, Pematang Pauh Campus, 13500 Pulau, Pinang, Malaysia, [2]Department of Civil and Environment Engineering, Universiti Teknologi PETRONAS, 32610 Seri Iskandar, Perak Darul Ridzuan, Malaysia

Corresponding Author: mzain.hashim@uitm.edu.my

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Abstract

Construction waste is rising due to population increase and urbanization in numerous nations. Since 1998, Malaysia's Construction Industry Development Board (CIDB) has promoted industrialized building system (IBS) adoption in local construction industries to reduce construction waste. The purposed of this study is to analyze the impacts of IBS in reducing construction waste in Kuching, Sarawak. There were five causes of construction waste were identified through an extensive literature review including of error in procurement method, frequent design changes, poor construction materials management, lack of supervision and incompetent site labors. However, if IBS system is used as the primary approach in the building business, these issues may be avoided. As a result, this research also emphasizes how the IBS system's effects on construction waste reduction. It was discovered that there were five impacts that have an influence on minimizing construction waste, including minimize the using of construction materials, reduction error during construction phase, improve site condition, reduction site workers and more durable. To identify the significant level of each variable, a questionnaire survey was carried out. Then, data would be analyses using Partial Least Square – Structural Equation Modeling method. As a result, all the five causes have a strong relationship with both reduction error during construction phase and improve site condition since these two variables show the highest score in PLS. Identifying the significance levels of waste production sources, as well as the influence IBS has on decreasing construction waste, would assist industry stakeholders in improving the efficiency of IBS in reducing construction waste.

Keywords: Industrialized Building System (IBS), Construction Waste, Partial Least Squares Structural Equation Modelling (PLS-SEM), Construction Waste Minimization, Smart Pls.

Introduction

Rapid building growth in Malaysia and other emerging nations is seriously threatening natural aggregate supplies and producing enormous quantities of concrete trash (Wong & Roslan, 2019). According to Department of Statistic Malaysia, our construction sector rebounded to 6.1 % year-on-year in the second quarter of 2022. Numerous projects, including high-rise commercial buildings, highways, expressways, tunnels, bridges, industrial structures, schools, hospitals, power plants, and housing initiatives, have been completed in Malaysia. The high demand of construction industry especially on development of houses and buildings for every year lead to the significant amount of construction waste. Waste from construction includes a wide variety of materials, including wood, bricks and blocks, cardboard, concrete, glass, metal, plastic, roofing material, soil, sand, and tiles (Muhaidin & Chan, 2018). The negative effects of construction waste on the environment also include soil and water contamination, the use of energy and natural resources, the degradation of the environment, and the destruction of the landscape (Zoghi & Kim, 2020)(Othuman Mydin et al., 2014)(Oladipo & Oni, 2012). Besides that, health concerns brought on by various diseases, traffic congestion, disputes with construction companies, drainage closures, and one of the biggest social effects of building waste include garbage being carried by rainwater and causing floods (Aboginije et al., 2020). Industrialized Building System (IBS) is one way for reducing waste during project construction. The initials "IBS" stand for "industrialized building system," which refers to the use of prefabricated parts in a building or construction project. Generally, this method able to speed up the process of project despite being environmentally friendly. The IBS was started in Malaysia in 1966 (Jing Le & Zainal, 2021). Prefabrication is a proven method for reducing construction waste in all types of building projects, including public housing, individual residences, and commercial buildings and the government sponsored environmental education and training may potentially benefit from the rise of prefabrication (Ahmad Bari et al., 2018).

Research Method

This research aims to investigate the impact of IBS technology-related factors on construction waste in Kuching, Sarawak. Quantitative research is defined as organized inquiry about a phenomenon through the collection of numerical data and the execution of statistical, mathematical, or computational techniques (Adedoyin, 2020).

Research study flow as follows; 1.Identifying and defining the problems - Discover the problems, 2.Literature Review- Understanding the topic by referring to the objective of research, 3.Sampling-Selection on sample design, 4.Design Questionnaires-Based on Literature Review, 5.Pilot Study-Distribute to 5 chosen parties to test the effectiveness of questionnaires, 6.Online Questionnaires-Using Google Form, 7.Data collection being process, and 8.Analyze the data using Structural Equation Modelling (SEM).

The population for this study research was determined to be the 498 registered firms in the CIDB database as well as in Sarawak list of firms. They are considered to be able to deliver more accurate and thorough data due to their knowledge and experience in the particular task area. Sample taking is the process of picking a sufficient number of respondents from a population. By using a sample, it is feasible to represent a sizable number of populations. The research was carried out by determining the number of samples from the population because it would be difficult to collect data from the complete population. Moreover, Slovin Formula is a statistical sampling which provide unbiased sampling. Equation below shows the Slovin Formula to be used in order to calculate the target population for this research. A 90%

confidence interval was chosen in this research, as it will provide more statistically significant findings (Polaris Marketing Research, 2012).

$$n = N/1+Ne^2$$

Where;

N = Population Size

n = Target Population

e = Error margin (10%) (Confidence interval = 90%)

$n = N/1+Ne^2$

$= 498/1+498(0.1)^2$

$= 83.3 \approx 84$ (Target Population)

In this research, a preliminary study was performed to test the questionnaire and enhance the methodology. Five individual's representatives of the intended audience were randomly picked to fill out the survey. Any possible biases or limits in the answer alternatives, as well as any confusion or difficulty in understanding the questions, may be uncovered using this method. Using the responses from the pilot study's participants, the researchers may revise questions that were too vague, add or remove answer alternatives, and alter the questionnaire's general layout. This helps make sure the final questionnaire is easy to understand and collects every relevant information. For this study, the Likert Scale was used in the questionnaire survey. The scale consists of a range of attitudes from one extreme to another on a 1 to 5-point scale, commonly known as a satisfaction scale. Since this research targets a specific group, the data will be analysed using PLS, which is a soft modelling method for Structural Equation Modelling (SEM) that makes no assumptions about the distribution of the data (Kwong-Kay, 2013). PLS is chosen due to the small sample size, limited application-specific theory, the importance of predictive accuracy, and the inability to guarantee an accurate model definition. Researchers may store and export their findings in a variety of formats. This function makes it easier to conduct in-depth analyses and write detailed reports for later use or to share results with others. Additionally, SmartPLS's graphical modeling window improves the study model's visualization, making it simpler to assess the interrelationships between variables and spot trends.

Results and Discussion

It is crucial to analyse respondents' experiences in questionnaire research in order to comprehend response patterns, improve data quality, refine survey designs, and develop informed interpretations of study results. To analyse the experience of respondents in questionnaire research, researchers may include questions about their familiarity with the research topic, such as their working experience in Industrialized Building System (IBS) projects, the number of IBS projects in which they have participated, and the type of IBS projects in which they have participated.

Experienced on Industrialized Building System (IBS)

It is crucial to analyse respondents' experiences in questionnaire research in order to comprehend response patterns, improve data quality, refine survey designs, and develop informed interpretations of study results. To analyse the experience of respondents in questionnaire research, researchers may include questions about their familiarity with the research topic, such as their working experience in Industrialized Building System (IBS) projects, the number of IBS projects in which they have participated, and the type of IBS projects in which they have participated. In order to accomplish the goals of the study, 84 participants actively participated in the survey. Most respondents had some familiarity with the IBS technology, with 47.6% having worked with IBS for 6-10 years. Meanwhile, those with expertise in IBS projects ranging from 1 to 5 years account for 40.5% of the total. Next, the study shows that 3.6% of participants had worked on an IBS project for 11–15 years, and that 2.4% have more than 20 years of expertise in the field. However, 6% of respondents said they had never worked on an IBS project before. In addition, none of them who has worked on an IBS project for between 16 and 20 years has responded.

Most of respondent agreed that Industrialized Building System (IBS) able to reduce construction waste. The proportion of respondents who have indicated that they are actively engaging in IBS initiatives. According to the data, 44% of respondents are engaged in four to six IBS operations, while 40% are engaged in one to three. Only 6% of respondents had ever taken part in any kind of IBS operation. In comparison, 4.8% of respondents reported participating in between 7 and 9 projects, and 4.8% reported participating in more than 10 initiatives. In conclusion, majority of the respondents in this survey being involve about four to six IBS projects. Precast concrete systems are the most popular form of IBS project, with 70.9% of respondents participating, followed by steel frame systems at 63.3%, prefabricated wood systems at 50.6%, and blockwork systems at 40.5%. Only 30.4% of those polled are actively involved in a formwork system. As a result, precast concrete system become the most well-known among survey participants.

Analysis of Factors Contributing to Construction Waste and Effect Industrialized Building System (IBS) in Minimizing Construction Waste

Respondents were asked to offer their ratings on a Likert Scale for each of the five types for both factors and effects in this section based on their degree of agreement with the variables leading to construction waste as well as the impacts of IBS in decreasing construction waste. Thus, data collection would be organized by using a spreadsheet and analysed PLS SEM using SmartPLS 4.0.

Measurement Model

The measurement model can be specified by identifying the associations among the observed indicators and their respective latent constructs. This is typically accomplished by indicating the factor loadings, which indicate the intensity and direction of the relationship between each indicator and its respective latent construct. The factor loadings estimate the extent to which the observed variables accurately represent the underlying constructs they are intended to measure. Figure 1.0 show the output measurement model based on the collection data.

The measurement model was dependable, as indicated by the indicators' high factor loadings. This indicates that the observed variables measure their respective constructs with reliability. The relationships between the indicators within each construct supported the convergence of validity. As the correlations between distinct constructs were less than the square root of the average variance extracted (AVE) values, discriminant validity was also established. The model fit indices, including the standardized root mean square residual (SRMR), indicated that the hypothesized model and the observed data were well matched.

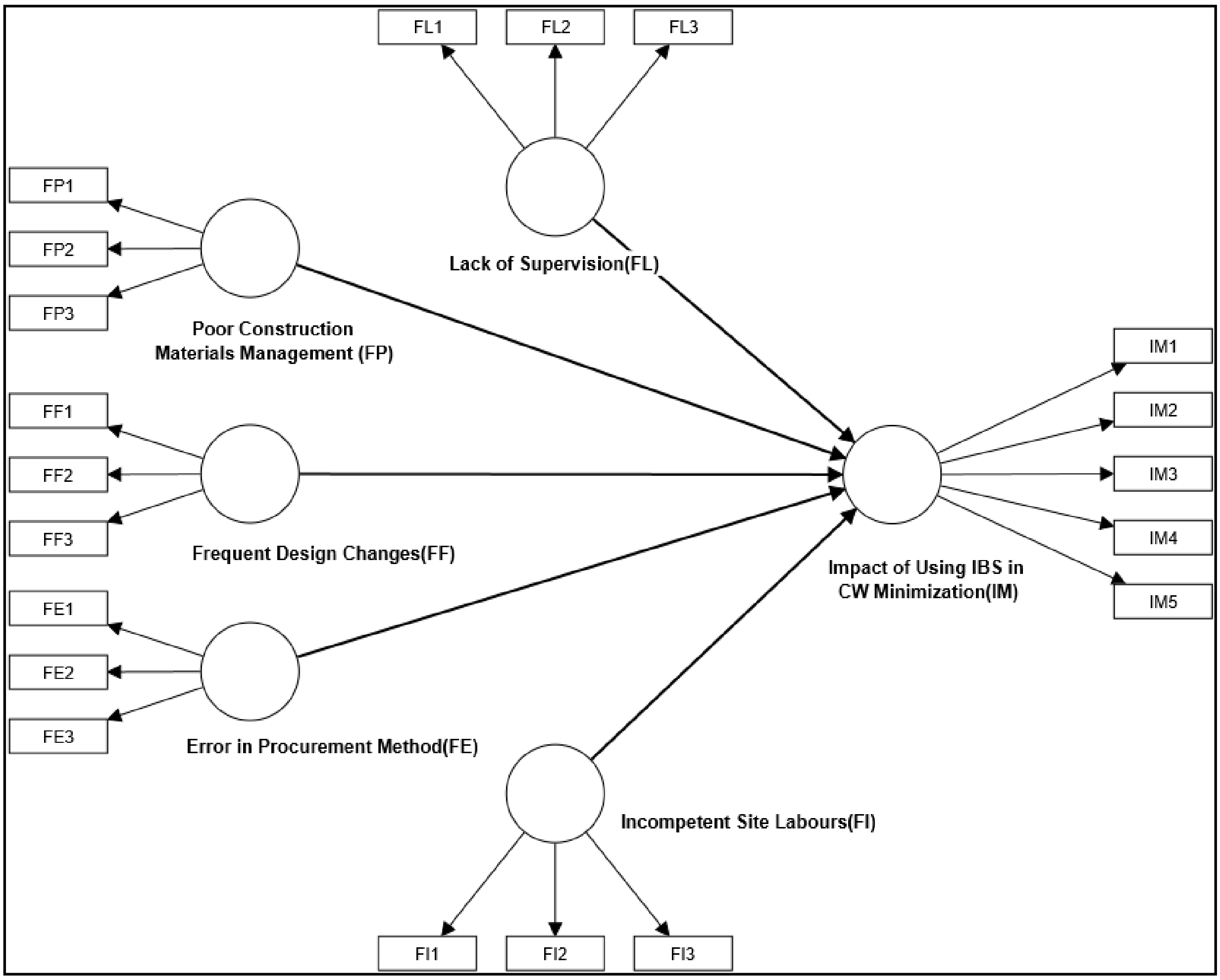

Figure 1.0: Measurement model

Loading Factor

In this data, there are six type of latent variable which are; Error in Procurement Method (FE), Poor Construction Material Management (FP), Frequent Design Changes (FF), Incompetent Site Labours (FI), Lack of Supervision (FL) and Effect Industrialized Building System in Minimizing Construction Waste (IM). Loading factors are interpreted by examining their size and statistical significance. Loading factors over 0.7 and below 0.4 are considered strong and weak, respectively. However, context and research field determine interpretation. Bootstrapping or other methods should be used to evaluate the loading factors' statistical significance. According to (Astuti, 2021), if a factor weighing is less than 0.40, it must be disregarded.

The outer loadings indicate how well each factor contributes to the latent constructs they represent. For example, the high loadings of FE2 (0.854) and FE3 (0.929) on Error in Procurement Method (FE) suggest that these indicators are strong representatives of procurement errors. Similarly, FF3 (0.959) has the highest loading on Frequent Design Changes (FF), indicating that clients' sudden unanticipated requests significantly impact design changes during construction. Incompetent Site Labourers (FI) is well represented by indicators FI2 (0.858) and FI3 (0.935), highlighting the significant issues caused by insufficient training and a shortage of skilled labor. Lack of Supervision (FL) is robustly represented by FL2 (0.857) and FL3 (0.918), pointing to the critical impact of neglecting supervision and miscalculations in construction. Poor Construction Materials Management (FP) is well captured by FP2 (0.864) and FP3 (0.894), underscoring the adverse effects of improper material storage and handling. For the dependent variable, Impact of Using IBS in CW Minimization (IM), indicators like IM3 (0.932) and IM5 (0.932) show strong loadings, suggesting that improving site conditions and reducing on-site workers are key benefits of using IBS. Overall shows how various factors contribute to construction waste and the effectiveness of using IBS in minimizing waste, highlighting areas for improvement in procurement, design changes, labor competency, supervision, and materials management.

Table 1
Outer Loading

	Outer loadings
FE1 <- Error in Procurement Method(FE)	0.795
FE2 <- Error in Procurement Method(FE)	0.854
FE3 <- Error in Procurement Method(FE)	0.929
FF1 <- Frequent Design Changes(FF)	0.845
FF2 <- Frequent Design Changes(FF)	0.837
FF3 <- Frequent Design Changes(FF)	0.959
FI1 <- Incompetent Site Labours(FI)	0.807
FI2 <- Incompetent Site Labours(FI)	0.858
FI3 <- Incompetent Site Labours(FI)	0.935
FL1 <- Lack of Supervision(FL)	0.797
FL2 <- Lack of Supervision(FL)	0.857
FL3 <- Lack of Supervision(FL)	0.918
FP1 <- Poor Construction Materials Management (FP)	0.728
FP2 <- Poor Construction Materials Management (FP)	0.864
FP3 <- Poor Construction Materials Management (FP)	0.894
IM1 <- Impact of Using IBS in CW Minimization(IM)	0.725
IM2 <- Impact of Using IBS in CW Minimization(IM)	0.889
IM3 <- Impact of Using IBS in CW Minimization(IM)	0.932
IM4 <- Impact of Using IBS in CW Minimization(IM)	0.889
IM5 <- Impact of Using IBS in CW Minimization(IM)	0.932

Composite Reliability and Convergent Validity

Meanwhile, the reliability test shows instrument internal consistency as for the dependability composite value and Cronbach's Alpha must exceed 0.7 (Triwidyati & Tentama, 2020). The internal consistency reliability of a measurement scale was evaluated using Cronbach's alpha. According to (Joseph F. Hair et al., 2013), believed Composite Reliability values and Cronbach's Alpha greater than 0.7 and 0.6 are acceptable. However, in this research, the outcome of data would be depended on Composite Reliability (rho_c). Cronbach alpha is unsteady due to the underestimation of construct reliability by the number of elements (Fauzi, 2022).

Starting with Cronbach's alpha, all constructs exhibit values above the threshold of 0.7, indicating acceptable internal consistency. Specifically, Error in Procurement Method (FE) scores 0.825, Frequent Design Changes (FF) 0.855, Impact of Using IBS in CW Minimization (IM) 0.922, Incompetent Site Labours (FI) 0.836, Lack of Supervision (FL) 0.82, and Poor Construction Materials Management (FP) 0.776. These values suggest that the items within each construct are reliably correlated.

Composite reliability is also strong across all constructs, with rho_a and rho_c values exceeding the 0.7 benchmark. For instance, Error in Procurement Method (FE) shows rho_a at 0.857 and rho_c at 0.896, Frequent Design Changes (FF) presents rho_a at 0.864 and rho_c at 0.913, and Impact of Using IBS in CW Minimization (IM) records rho_a at 0.93 and rho_c at 0.943. Similar reliability is seen for Incompetent Site Labours (FI), Lack of Supervision (FL), and Poor Construction Materials Management (FP), indicating consistent measurement of underlying concepts by their indicators.
Convergent validity, assessed through the average variance extracted (AVE), reveals satisfactory results for all constructs, with values well above the 0.5 threshold. Error in Procurement Method (FE) has an AVE of 0.742, Frequent Design Changes (FF) 0.778, Impact of Using IBS in CW Minimization (IM) 0.769, Incompetent Site Labours (FI) 0.754, Lack of Supervision (FL) 0.737, and Poor Construction Materials Management (FP) 0.692. These AVE values indicate that a significant portion of the variance in the indicators is explained by the constructs, ensuring good convergent validity.
In summary, the measurement model exhibits strong reliability and validity across all constructs. The high Cronbach's alpha values indicate good internal consistency, while the composite reliability values confirm the reliability of the constructs. Additionally, the AVE values support the constructs' convergent validity. These findings affirm that the constructs are appropriately measured, providing a solid foundation for further analysis, such as exploring the relationships between these constructs and their impact on construction waste minimization using IBS.

Table 2
Construct Reliability and Validity For Measurement Model

	Cronbach's alpha (> 0.7)	**Composite reliability (rho_a) > 0.7**	**Composite reliability (rho_c) > 0.7**	**Average variance extracted (AVE) > 0.5**
Error in Procurement Method(FE)	0.825	0.857	0.896	0.742
Frequent Design Changes(FF)	0.855	0.864	0.913	0.778
Impact of Using IBS in CW Minimization(IM)	0.922	0.93	0.943	0.769
Incompetent Site Labours(FI)	0.836	0.867	0.902	0.754
Lack of Supervision(FL)	0.82	0.832	0.894	0.737
Poor Construction Materials Management(FP)	0.776	0.81	0.87	0.692

Discriminant Validity
Table 3.0 demonstrates that the square root of the AVE of all constructs is larger than the correlation with other constructs, showing that discriminant validity has been established for this research. Table 4.0 illustrates the findings of the discriminant validity evaluation using the results using HTMT, with the HTMT ratio for all constructs being less than 0.85. According to (Rasoolimanesh, 2022), the value of HTMT should be less than 0.85 or 0.9, thus the hypothesis HTMT=1 should be rejected when using the inference statistic.

Table 3.0
Outcome of Discriminant Validity Assessment Using Fornell-Larcker Criterion

	Error in Procurement Method(FE)	Frequent Design Changes(FF)	Impact of Using IBS in CW Minimization(IM)	Incompetent Site Labours(FI)	Lack of Supervision(FL)	Poor Construction Materials Management (FP)
Error in Procurement Method(FE)	0.861					
Frequent Design Changes(FF)	0.74	0.882				
Impact of Using IBS in CW Minimization(IM)	0.668	0.624	0.877			
Incompetent Site Labours(FI)	0.542	0.781	0.623	0.868		
Lack of Supervision(FL)	0.664	0.6	0.994	0.615	0.859	
Poor Construction Materials Management (FP)	0.803	0.592	0.753	0.765	0.761	0.832

The provided table represents a matrix used to assess discriminant validity within a model, often in the context of Structural Equation Modeling (SEM), using the Fornell-Larcker criterion. This criterion ensures that constructs in the model are distinct from each other by comparing the square root of the Average Variance Extracted (AVE) for each construct against its correlations with other constructs. Typically, the diagonal elements of the matrix should represent the square root of the AVE for each construct. However, in this table, the diagonal values are greater than 1 for some constructs, suggesting they may not be AVE values but another metric. Off-diagonal values represent correlations between different constructs, such as the correlation between "Error in Procurement Method" (FE) and "Frequent Design Changes" (FF), which is 0.740. To apply the Fornell-Larcker criterion correctly, each diagonal value should be higher than the off-diagonal values in its respective row and column, indicating that a construct is more strongly correlated with its indicators than with other constructs. Without confirming that the diagonal values are indeed the square root of AVE, it is challenging to determine discriminant validity conclusively. If the values were accurate, they would need to be compared with the correlations in their respective rows and columns to ensure that each construct is distinct, highlighting areas where the model might require adjustments.

Table 4.0

Outcome of Discriminant Validity Assessment Using Heterotrait-Monotrait (Htmt) Ratio

	Heterotrait-monotrait ratio (HTMT)
Frequent Design Changes(FF) <-> Error in Procurement Method(FE)	0.868
Impact of Using IBS in CW Minimization(IM) <-> Error in Procurement Method(FE)	0.763
Impact of Using IBS in CW Minimization(IM) <-> Frequent Design Changes(FF)	0.700
Incompetent Site Labours(FI) <-> Error in Procurement Method(FE)	0.623
Incompetent Site Labours(FI) <-> Frequent Design Changes(FF)	0.912
Incompetent Site Labours(FI) <-> Impact of Using IBS in CW Minimization(IM)	0.704
Lack of Supervision(FL) <-> Error in Procurement Method(FE)	0.803
Lack of Supervision(FL) <-> Frequent Design Changes(FF)	0.708
Lack of Supervision(FL) <-> Impact of Using IBS in CW Minimization(IM)	1.140
Lack of Supervision(FL) <-> Incompetent Site Labours(FI)	0.736
Poor Construction Materials Management (FP) <-> Error in Procurement Method(FE)	0.991
Poor Construction Materials Management (FP) <-> Frequent Design Changes(FF)	0.706
Poor Construction Materials Management (FP) <-> Impact of Using IBS in CW Minimization(IM)	0.881
Poor Construction Materials Management (FP) <-> Incompetent Site Labours(FI)	0.934
Poor Construction Materials Management (FP) <-> Lack of Supervision(FL)	0.952

The Heterotrait-Monotrait Ratio (HTMT) analysis reveals insights into the discriminant validity of various constructs in the model. Starting with the relationship between Frequent Design Changes (FF) and Error in Procurement Method (FE), the HTMT value of 0.868 is slightly above the threshold of 0.85. This suggests potential issues with discriminant validity, indicating that these constructs may not be entirely distinct. In contrast, the relationship between the Impact of Using IBS in CW Minimization (IM) and Error in Procurement Method (FE) shows an HTMT value of 0.763, which is below the threshold. This indicates good discriminant validity, suggesting that the Impact of Using IBS in CW Minimization is distinct from Error in Procurement Method. Similarly, the HTMT value for the relationship between Impact of Using IBS in CW Minimization (IM) and Frequent Design Changes (FF) is 0.7, also indicating good discriminant validity between these constructs. The relationship between Incompetent Site Labours (FI) and Error in Procurement Method (FE) has an HTMT value of 0.623, which is well below 0.85, suggesting good discriminant validity. However, the relationship between Incompetent Site Labours (FI) and Frequent Design Changes (FF) shows an HTMT value of 0.912, exceeding the threshold and indicating potential issues with discriminant validity. Conversely, the HTMT value for the relationship between Incompetent Site Labours (FI) and Impact of Using IBS in CW Minimization (IM) is 0.704, indicating good discriminant validity. For the relationship between Lack of Supervision (FL) and Error in Procurement Method (FE), the HTMT value is 0.803, indicating good discriminant validity. Similarly, the HTMT value for Lack of Supervision (FL) and Frequent Design Changes (FF) is 0.708, also indicating good discriminant validity. However, the relationship between Lack of Supervision (FL) and Impact of Using IBS in CW Minimization (IM) has an HTMT value of 1.14, significantly exceeding the threshold. This indicates a severe issue with discriminant validity between these constructs.

On the other hand, the HTMT value for Lack of Supervision (FL) and Incompetent Site Labours (FI) is 0.736, indicating good discriminant validity. The relationship between Poor Construction Materials Management (FP) and Error in Procurement Method (FE) has an HTMT value of 0.991, which is very close to 1, indicating severe issues with discriminant validity. Conversely, the HTMT value for Poor Construction Materials Management (FP) and Frequent Design Changes (FF) is 0.706, indicating good discriminant validity. However, the HTMT value for Poor Construction Materials Management (FP) and Impact of Using IBS in CW Minimization (IM) is 0.881, slightly above 0.85, suggesting potential issues with discriminant validity. Last, the relationship between Poor Construction Materials Management (FP) and Incompetent Site Labours (FI) shows an HTMT value of 0.934, indicating potential issues with discriminant validity. Similarly, the HTMT value for Poor Construction Materials Management (FP) and Lack of Supervision (FL) is 0.952, also exceeding the threshold and indicating issues with discriminant validity. In summary, the HTMT analysis highlights several pairs of constructs with potential discriminant validity issues, particularly those involving Lack of Supervision, Incompetent Site Labours, and Poor Construction Materials Management. These findings suggest the need for further refinement of the measurement model to ensure that each construct uniquely captures its intended concept.

Structural Model

The relationship between the constructs is tested in the second step of SEM analysis. It is also known as a causal connection in order to express the theoretical structure between the constructs of meaningfulness as well as significance (Joseph Franklin Hair et al., 2016).

Probability Value (P-Value

A significance threshold of = 0.05 was applied, implying that p-values less than 0.05 were statistically significant. Based on Table 5.0, several connections in the structural model were determined to be statistically significant, as shown by p-values less than 0.05, according to the study. These results imply that there is substantial evidence to indicate the occurrence of significant correlations between the latent components. From the data, it shows that all of the proposed factors give the significant impact to Effect Industrialized Building System (IBS) in Minimizing Construction Waste.

Table 5.0
Path Coefficients Result From Bootstrapping Analysis In Pls-Sem

	Original sample (O)	**Sample mean (M)**	**Standard deviation (STDEV)**	**T statistics (|O/STDEV|)**	**P values**
Error in Procurement Method(FE) -> Frequent Design Changes(FF)	0.7410	0.7430	0.0800	9.2990	**0.0000**
Error in Procurement Method(FE) -> Impact of Using IBS in CW Minimization(IM)	-0.0180	-0.0150	0.6180	0.0300	0.9760
Frequent Design Changes(FF) -> Impact of Using IBS in CW Minimization(IM)	0.0700	0.0680	0.6310	0.1110	0.9120
Frequent Design Changes(FF) -> Poor Construction _Materials Management (FP)	0.5920	0.5940	0.0880	6.7410	**0.0000**
Incompetent Site Labours(FI) -> Error in Procurement Method(FE)	0.5430	0.5490	0.1070	5.0540	**0.0000**
Incompetent Site Labours(FI) -> Impact of Using IBS in CW Minimization(IM)	-0.0200	-0.0150	0.6250	0.0310	0.9750
Lack of Supervision(FL) -> Impact of Using IBS in CW Minimization(IM)	0.9780	0.9730	0.0170	56.0110	**0.0000**
Poor Construction Materials Management (FP) -> Impact of Using IBS in CW Minimization(IM)	-0.0050	-0.0070	0.5860	0.0080	0.9940
Poor Construction Materials Management (FP) -> Lack of Supervision(FL)	0.7610	0.7630	0.0650	11.6990	**0.0000**

The path coefficients result from the bootstrapping analysis in PLS-SEM provides insights into the relationships between various constructs. The table shows the original sample (O), sample mean (M), standard deviation (STDEV), T statistics (|O/STDEV|), and P values for each relationship.

Firstly, the relationship between Error in Procurement Method (FE) and Frequent Design Changes (FF) has a path coefficient of 0.741, a T statistic of 9.299, and a P value of 0.000. This indicates a strong, significant positive relationship, suggesting that errors in procurement methods are strongly associated with frequent design changes. Conversely, the relationship between Error in Procurement Method (FE) and the Impact of Using IBS in CW Minimization (IM) has a path coefficient of -0.018, a T statistic of 0.03, and a P value of 0.976. This suggests a negligible and statistically insignificant relationship, indicating that errors in procurement methods do not significantly impact the effectiveness of IBS in minimizing construction waste. The path coefficient between Frequent Design Changes (FF) and the Impact of Using IBS in CW Minimization (IM) is 0.07, with a T statistic of 0.111 and a P value of 0.912. This relationship is also insignificant, implying that frequent design changes do not significantly affect the impact of IBS on waste minimization. On the other hand, the relationship between Frequent Design Changes (FF) and Poor Construction Materials Management (FP) shows a path coefficient of 0.592, a T statistic of 6.741, and a P value of 0.000. This indicates a significant positive relationship, suggesting that frequent design changes contribute significantly to poor management of construction materials. Incompetent Site Labours (FI) show a positive and significant relationship with Error in Procurement Method (FE), with a path coefficient of 0.543, a T statistic of 5.054, and a P value of 0.000. This suggests that incompetent site laborers are significantly associated with errors in procurement methods. However, the relationship between Incompetent Site Labours (FI) and the Impact of Using IBS in CW Minimization (IM) is insignificant, with a path coefficient of -0.02, a T statistic of 0.031, and a P value of 0.975, indicating no significant effect. The relationship between Lack of Supervision (FL) and the Impact of Using IBS in CW Minimization (IM) is highly significant, with a path coefficient of 0.978, a T statistic of 56.011, and a P value of 0.000. This suggests that adequate supervision plays a crucial role in maximizing the impact of IBS in minimizing construction waste. Poor Construction Materials Management (FP) does not significantly impact the effectiveness of IBS in minimizing construction waste, as indicated by a path coefficient of -0.005, a T statistic of 0.008, and a P value of 0.994. However, it has a strong and significant positive relationship with Lack of Supervision (FL), with a path coefficient of 0.761, a T statistic of 11.699, and a P value of 0.000, indicating that poor management of construction materials is significantly associated with a lack of supervision. The results highlight several key relationships. Errors in procurement methods and frequent design changes are significantly related, as are frequent design changes and poor construction materials management. Incompetent site laborers significantly impact procurement errors but not the use of IBS in minimizing waste. Lack of supervision significantly affects the impact of IBS in waste minimization, emphasizing the importance of adequate supervision. Poor construction materials management significantly correlates with lack of supervision but does not significantly impact the effectiveness of IBS in waste minimization. These insights can help guide improvements in procurement, supervision, and material management practices to enhance construction efficiency and waste reduction.

Variance Inflation Factor (VIF)

According to (Daoud, 2017) and (Oke et al., 2019), if any of the VIF values exceeds 5 or 10, it indicates that the related regression coefficients are poorly estimated due to multicollinearity. In conclusion, Table 7.0 show VIF values less than 5.0 or 10.0 are generally regarded as acceptable, suggesting a low degree of multicollinearity.

Table 6.0
Collinearity Statistics (VIF) - Inner Model

	VIF
Error in Procurement Method(FE) -> Frequent Design Changes(FF)	1
Error in Procurement Method(FE) -> Impact of Using IBS in CW Minimization(IM)	13.61
Frequent Design Changes(FF) -> Impact of Using IBS in CW Minimization(IM)	12.894
Frequent Design Changes(FF) -> Poor Construction Materials Management (FP)	1
Incompetent Site Labours(FI) -> Error in Procurement Method(FE)	1
Incompetent Site Labours(FI) -> Impact of Using IBS in CW Minimization(IM)	13.73
Lack of Supervision(FL) -> Impact of Using IBS in CW Minimization(IM)	2.83
Poor Construction Materials Management (FP) -> Impact of Using IBS in CW Minimization(IM)	18.065
Poor Construction Materials Management (FP) -> Lack of Supervision(FL)	1

The collinearity statistics (VIF) for the inner model provide crucial insights into the multicollinearity among the predictor variables in the structural equation modeling (SEM) analysis. Variance Inflation Factor (VIF) values above 10 generally indicate high collinearity, which can distort the regression coefficients and lead to unreliable results.
Starting with the relationship between Error in Procurement Method (FE) and Frequent Design Changes (FF), the VIF value is 1, indicating no collinearity issues. Similarly, the relationship between Frequent Design Changes (FF) and Poor Construction Materials Management (FP), as well as the relationship between Incompetent Site Labours (FI) and Error in Procurement Method (FE), both have VIF values of 1, suggesting no multicollinearity concerns. However, the relationship between Error in Procurement Method (FE) and the Impact of Using IBS in CW Minimization (IM) has a high VIF value of 13.61, indicating significant collinearity. This suggests that the predictor variable, Error in Procurement Method, is highly correlated with other predictors of the Impact of Using IBS in CW Minimization, potentially distorting the regression analysis. Similarly, the relationship between Frequent Design Changes (FF) and the Impact of Using IBS in CW Minimization (IM) has a VIF value of 12.894, indicating high collinearity. Incompetent Site Labours (FI) also show high collinearity with the Impact of Using IBS in CW Minimization (IM), with a VIF value of 13.73. The highest VIF value is observed in the relationship between Poor Construction Materials Management (FP) and the Impact of Using IBS in CW Minimization (IM), at 18.065, indicating severe multicollinearity. In contrast, the relationship between Lack of Supervision (FL) and the Impact of Using IBS in CW Minimization (IM) has a moderate VIF value of 2.83, which is below the threshold of concern and indicates that collinearity is not a significant issue here. The relationship between Poor Construction Materials Management (FP) and Lack of Supervision (FL) also has a VIF value of 1, indicating no collinearity concerns. The analysis reveals significant multicollinearity issues in the relationships involving the Impact of Using IBS in CW Minimization (IM), particularly with Error in Procurement Method (FE), Frequent Design Changes (FF), Incompetent Site Labours (FI), and Poor Construction Materials Management (FP). These high VIF values suggest that these predictors are highly correlated with each other, which could distort the regression results and lead to unreliable conclusions. To address these issues, it is recommended to consider strategies such as removing or combining highly correlated predictors, applying dimensionality reduction techniques like

Principal Component Analysis (PCA), or using regularization methods like Ridge Regression to mitigate the effects of multicollinearity. By addressing these multicollinearity issues, the model can provide more reliable and interpretable results, ultimately enhancing the understanding of factors influencing the effectiveness of IBS in construction waste minimization.

Quality Model

The quality of the findings provided by the Partial Least Square approach is determined by a number of variables, including the data quality, the suitability of the selected model, the researcher's comprehension of the underlying ideas, and the right interpretation of the results. These measurements give information on how well the model matches the data and how well it captures the underlying theoretical principles. As a result, the model's quality remains consistent.

Coefficient of Determination, R^2 and Stone-Geisser, Q^2

Table 7.0
Coefficient of Determination, R^2

	R-square	R-square adjusted
Error in Procurement Method(FE)	0.294	0.286
Frequent Design Changes(FF)	0.548	0.543
Impact of Using IBS in CW Minimization(IM)	0.989	0.988
Lack of Supervision(FL)	0.58	0.575
Poor Construction Materials Management (FP)	0.35	0.343

The Coefficient of Determination (R^2) and the adjusted R^2 values provide insights into how well the independent variables explain the variance in the dependent variables within the model. These metrics are crucial in assessing the explanatory power of the model.
Starting with the Error in Procurement Method (FE), the R^2 value is 0.294 and the adjusted R^2 is 0.286. This indicates that approximately 29.4% of the variance in Error in Procurement Method can be explained by the independent variables included in the model. The adjusted R^2, which accounts for the number of predictors in the model, is slightly lower, suggesting that some explanatory power might be lost when adjusting for the number of variables. For Frequent Design Changes (FF), the R^2 is 0.548 and the adjusted R^2 is 0.543. This suggests that 54.8% of the variance in Frequent Design Changes is explained by the model, indicating a moderately strong explanatory power. The minimal difference between R^2 and adjusted R^2 indicates that the model is well-specified with relevant predictors. The Impact of Using IBS in CW Minimization (IM) shows an exceptionally high R^2 value of 0.989 and an adjusted R^2 of 0.988. This implies that the model explains 98.9% of the variance in the Impact of Using IBS in CW Minimization, indicating a very strong explanatory power. The high adjusted R^2 confirms that nearly all of the variance in IM is accounted for by the independent variables, making it a robust predictor. In the case of Lack of Supervision (FL), the R^2 is 0.58 and the adjusted R^2 is 0.575. This suggests that 58% of the variance in Lack of Supervision is explained by the model. The close values of R^2 and adjusted R^2 indicate a well-fitted model with substantial explanatory power. Lastly, for Poor Construction Materials Management (FP), the R^2 value is 0.35 and the adjusted R^2 is 0.343. This indicates that 35% of the variance in Poor

Construction Materials Management is explained by the model. The small difference between R^2 and adjusted R^2 shows that the model's predictors are relevant and contribute significantly to explaining the variance in FP. The R^2 and adjusted R^2 values collectively suggest that the model has varying levels of explanatory power for different constructs. The Impact of Using IBS in CW Minimization (IM) is exceptionally well-explained by the model, while Frequent Design Changes (FF) and Lack of Supervision (FL) also show strong explanatory power. Error in Procurement Method (FE) and Poor Construction Materials Management (FP) have moderate explanatory power. These results indicate that while the model is effective in explaining most of the variance for certain constructs, there is room for improvement in others. Further refinement and inclusion of additional relevant variables could enhance the explanatory power for constructs with lower R^2 values (Hussain et al., 2018).

Table 9.0
Stone-Geisser, Q2

	SSO	SSE	Q^2 (=1-SSE/SSO)
Error in Procurement Method(FE)	252	135.666	0.462
Frequent Design Changes(FF)	252	127.239	0.495
Impact of Using IBS in CW Minimization(IM)	420	148.902	0.645
Incompetent Site Labours(FI)	252	130.293	0.483
Lack of Supervision(FL)	252	136.75	0.457
Poor Construction Materials Management (FP)	252	154.687	0.386

The Stone-Geisser Q^2 values reported in Table 9.0 assess the predictive relevance of the constructs within the model. This metric is derived using a blindfolding procedure and is particularly useful in PLS-SEM to evaluate the model's ability to predict the data. A Q^2 value greater than 0 indicates that the model has predictive relevance for the respective construct. Error in Procurement Method (FE): The Q^2 value is 0.462, indicating that the model explains about 46.2% of the variation in the Error in Procurement Method construct. This suggests moderate predictive relevance, showing that the model is reasonably effective in predicting errors in procurement. Frequent Design Changes (FF): The Q^2 value for this construct is 0.495, which is slightly higher than that for FE. This value indicates that the model predicts nearly 49.5% of the variation in Frequent Design Changes, suggesting good predictive relevance. Impact of Using IBS in CW Minimization (IM): This construct shows a Q^2 value of 0.645, the highest among all the constructs evaluated. It implies a strong predictive relevance, with the model explaining 64.5% of the variation in the impact of using IBS for construction waste minimization. This highlights the model's strength in predicting how effectively IBS can minimize construction waste. Incompetent Site Labours (FI): With a Q^2 value of 0.483, this construct also demonstrates moderate predictive relevance. The model is capable of explaining 48.3% of the variance in issues related to incompetent site laborers, which is indicative of its usefulness in predicting problems associated with workforce competencies in construction projects. Lack of Supervision (FL): The predictive relevance for Lack of Supervision is slightly lower at 0.457. This suggests that while the model can still predict issues related to supervision in construction projects, it does so with moderate effectiveness, covering about 45.7% of the variance. Poor Construction Materials Management (FP): This construct has the lowest Q^2 value at 0.386, indicating limited predictive relevance. The model explains only 38.6% of the variation in poor construction materials management, suggesting that additional factors not included in the model may be influencing this construct. The Stone-

Geisser Q^2 values provide valuable insights into the predictive capabilities of the model across various constructs related to construction project management. Constructs related to the impact of using IBS in minimizing waste and frequent design changes are predicted with higher relevance, showcasing the model's strength in these areas. However, the lower Q^2 values for constructs like Poor Construction Materials Management suggest that there are additional influences not captured by the model, indicating potential areas for further investigation or model refinement. The overall results suggest that while the model is effective in predicting certain aspects of construction project management, enhancements could be made to improve its predictive accuracy, especially in areas where the Q^2 values are lower.

Conclusion

The analyses conducted using PLS-SEM on various constructs related to construction project management provide a robust understanding of the dynamics at play. The model demonstrates strong reliability and validity, with most constructs showing good internal consistency and discriminant validity, though some issues were identified with specific constructs such as Incompetent Site Labours and Frequent Design Changes. The predictive relevance (Q^2 values) indicates that the model is particularly effective at predicting the impact of using IBS in minimizing construction waste and the dynamics of frequent design changes, suggesting that these aspects of the model are well-developed. However, areas such as Poor Construction Materials Management indicate lower predictive relevance, highlighting opportunities for further model refinement. Additionally, significant multicollinearity in some predictors suggests the need for careful consideration of input variables to improve model stability and interpretability. Overall, the model provides valuable insights but could benefit from further refinement to enhance its accuracy and predictive power in less robust areas.

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Corresponding Author

Mohamad Zain Hashim
Civil Engineering Studies, College of Engineering,
Universiti Teknologi MARA Cawangan Pulau Pinang,
Pematang Pauh Campus, 13500 Pulau, Pinang, MALAYSIA
Email: mzain.hashim@uitm.edu.my

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