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# Strategies Performance Practices of Contractors in Driving the Effectiveness of Industrialized Building System (IBS) Implementation

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## ABSTRACT

The Industrialised Building System (IBS) has recently been brought forward as a new methodology in the construction industry for improving the productivity, quality of the projects and their sustainability. IBS has a 70% minimum required to be met by public projects and 50% is to be met by private projects. Nonetheless, the IBS is currently proving problematic in practice as the technical capability is lacking and investment in capital is huge at the initial stage. To this end, the objective of this study is to investigate the IBS practices construct, including the technology, organization, and environment dimensions, in Malaysia. This study also assesses reliability and predictiveness of the results. A quantitative method was used in Selangor by making use of precast concrete from contractor questionnaires. The data were analysed using SPSS version 22.0 for descriptive statistics, and Smart PLS-SEM for structural model assessment. The findings showed that the highest mean value (4.32) of time, followed by popularity of IBS (4.31), and low mean value construction cost (4.04). In contrast, when evaluating the predictive capacity of the model on IBS performance, the $R^2$ value is very high 0.670. Hence, strategies for enhancing contractors' performance practices not only propel the success of IBS implementation; it also helps to transform Malaysia's construction sector in accordance with the aspirations of the Fourth Industrial Revolution (IR 4.0) and the Sustainable Development Agenda.

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## 1. Introduction

The construction sector is the backbone of economic growth; however, it suffers challenges related to productivity, quality, safety, and sustainability that have yet to be addressed in the broader community. As the construction sector becomes more efficient and performing, the Industrialised Building System (IBS) has emerged as a transformative platform of construction systems based on industrial systems that are integrated with prefabrication, factory-based production, and automation of plant operation processes. IBS has broad application recognition that it has the potential to shorten construction time, improve quality consistency, reduce on-site waste, and decrease reliance on unskilled labour. Due to its strategic significance, the Malaysian authorities have proactively encouraged IBS adoption by requiring a minimum of 70% IBS utilisation in public sector projects and 50% in private developments (MOF, 2020).

The Industrialised Building System (IBS), widely adopted worldwide by various countries, in Malaysia represents a strategic move for improving construction productivity, quality, and sustainability. IBS started in 1963 in Malaysia and has been promoted with policy and regulatory frameworks. Despite ongoing promotion, IBS implementation success is variable at the contractor level, revealing that effectiveness depends on both policy support and contractors' performance (Yusof et al., 2024). Though precast systems, automation, Building Information Modelling (BIM), and digital project management tools have radically revolutionised construction practice worldwide, their use in IBS projects in Malaysia has not consistently led to good project outcomes. The presence and application of technologies do not solely determine IBS performance but are closely related to their acceptance in organisational structures, work processes, and project conditions. Therefore, measuring IBS performance requires a holistic approach, considering not just adoption rates but also effective implementation and management at the project level (Jaffar & Lee, 2020).

While the government has aggressively encouraged IBS as a modern construction practice to enhance productivity, quality, safety, and sustainability, Malaysian contractors still do not consistently implement IBS to the best of their ability. The problem is not a lack of policies or technologies, but inadequate adoption at the contractor level. Contractors face technological preparedness shortages, skills gaps, workforce inadequacy, weak organisational structure, low coordination, and cost containment challenges. Consequently, adoption is often regulatory-driven rather than performance-driven, leading to irregular construction outcomes and underperformance. These limitations cause wasted resources, delays, and poor project results, preventing full utilisation of IBS advantages. Furthermore, adherence to requirements, rather than optimization of performance, tends to govern IBS adoption especially in government as opposed to commercial projects. As a result, outcomes such as reduced reliance on foreign labour, increased site safety, and improved quality and productivity have yet to be fully realised. This has also contributed to the negative perception of the construction industry as labour-intensive, risky, and less suitable for younger generations (Irwan Hafizy Md Arif et al., 2020; MOF, 2020).

These concerns highlight the need to move beyond punitive policies and adoption targets and to understand how IBS practices are implemented in real projects. Modern technology and building system innovations are strongly linked with IBS operations in Malaysia. Many studies evaluate IBS performance through technological, organisational, work process, environmental, and policy dimensions. Technological advancements and building system developments are important drivers for improving IBS implementation effectiveness at the project level (Irwan Hafizy Md Arif et al., 2020). Although Malaysia benefits from strong policy support for IBS, contractor-level performance remains uneven, especially in government projects (Kasim et al., 2021). Previous studies often treat technological, organisational, and environmental factors individually, lacking understanding of their combined effects on IBS performance. Moreover, IBS implementation is mostly influenced by regulatory needs (such as CIDB requirements) rather than performance enhancement, indicating a shortage of comprehensive and empirically tested evaluation approaches (Qin et al., 2020). These gaps highlight the lack of empirically validated, holistic approaches to evaluating IBS practices and underscore the need for systematic investigation using an integrated framework such as the Technology–Organisation–Environment (TOE) model.

Thus, this study aims to ascertain the effectiveness of IBS practices among contractors participating in government construction projects in Malaysia, focusing on precast concrete systems in Selangor. Using the Technology–Organisation–Environment (TOE) framework, the investigation examines the combined influence of technological, organisational, and environmental factors on IBS practice performance at the project level. Employing a quantitative methodology, the study validates the IBS practices construct for reliability, consistency, and predictive validity. The study also identifies performance constraints and implementation gaps faced by contractors, providing empirical evidence to inform IBS implementation strategies. This work supports Malaysia's transition from traditional to industrialised construction practices, aligning the construction sector with developed economies and Industry 4.0 aspirations(Zahari & W. Muhamad Radzi, 2021).

In this study, three main ways are made possible from this study to the IBS and construction management literature. The first focus is on performance-based evaluation as opposed to IBS implementation, thus offering empirical insights into how contractors in government employ IBS practices at the contractor level in their construction projects. Secondly, it devises and validates a TOE-based IBS performance evaluation model targeting the inadequacy of holistic, empirically tested models in the Malaysian context. Thirdly, by concentrating on precast concrete systems in Selangor, an empirical study in this area provides practical evidence to provide support and guidance for better-designed IBS implementation approaches by enabling a shift from traditional construction modes to technology-driven and industrial construction methods in a congruent way with developed construction economies.

### *1.1 Chronology of IBS in Malaysia*

Modern technologies and building systems have made significant marks on the construction industry. Of these developments, the Industrialised Building System (IBS) is one of the new approaches, providing efficacy, quality, and consistency in project implementation. IBS was initially introduced in Malaysia in 1963. However, its widespread acceptance has not been strong in comparison with developed nations (Yunus et al., 2020; Yusof et al., 2024). Recognising its potential, the Construction Industry Development Board (CIDB) has recommended IBS from 1998, and government mandates require IBS for a minimum of 70% of components in public sector projects and 50% in private sector projects (Yusof et al., 2024). Despite these initiatives, the adoption of IBS has remained slow, reflecting persistent structural and operational challenges.

The local and global labor productivity benchmarks reported in CITP 2016-2020 reflect the limited modernization of Malaysian construction methods and practices with the challenges of construction becoming increasingly serious as a result of using conventional methods. The Malaysian construction authorities are actively to promoting innovation and technology in modern methods of construction. The IBS roadmap 2011-2015 targeted an overall adoption rate of 100 percent implementing IBS project, with an IBS score of 70 for public sector project and a score of 50 for private sector project. The IBS implementation chronology is as shown in Figure 1.

However, the adoption of IBS was slow, which is an indication of ongoing structural and operational issues. IBS describes a construction system in which manufacturers manufacture components in factory or on-site, followed by shipping them to the site to set manufacturing standards (MOF, 2020). It also involves the engineering/production of structures in enclosed and open environments with controlled environments where structural elements are manufactured (Jaffar & Lee, 2020). Characteristic features of this are, the design of prefabricated components, controlled environment production, and the systematic, orderly logistics with systematic on-site installation (Yunus et al., 2020).

IBS defining features include prefabrication, pre-production in a controlled environment, and organized logistics and coordinated on-site installation. IBS also aims to be a creative and innovative construction method in which construction of components in large amounts is produced at low cost while providing a controlled environment (on-site or off-site), supported by well-organised logistics and process with a systematic on-site installation mechanism and planning and management (Zairul, 2021). In contrast, other researchers define IBS as an environment that builds constructions under predetermined conditions, on or off the site, and moves, positions and assemblages elements to produce the finished structure (Jaffar & Lee, 2020). Malaysian contractors are divided into size categories, from small (G1–G3) through medium (G4–G5) and large firms (G6–G7), and due to the harsh work environment for these firms many of them depend on foreign labour. Policies implemented in 2008 also drove IBS adoption to reduce reliance on foreign workers in public sector projects (with 70% IBS component requirement) ((MOF, 2020).

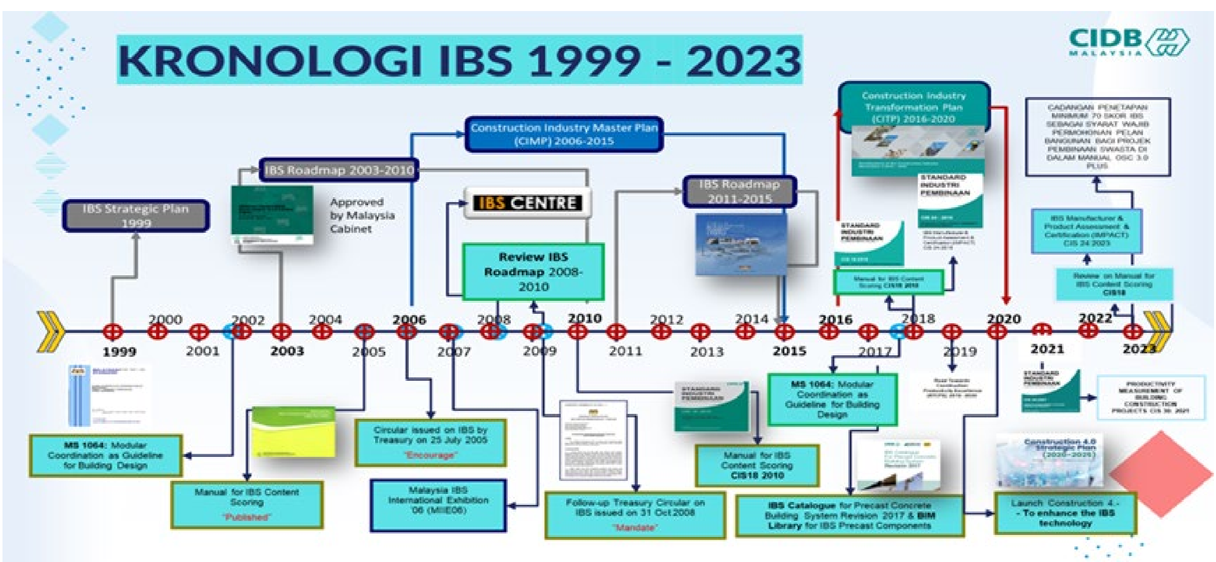


**Figure 1** Chronology of IBS Implementation in Malaysia

### *1.2 IBS Practices in Malaysia*

The IBS has become a strategic enabler of Malaysia's construction industry, supporting competitiveness in global markets and alignment with contemporary technological trends. In the context of the Fourth Industrial Revolution (IR 4.0), it has been stated that this transformation centres on automating processes, robotics, and the integration of information technology, which shifts construction labour from manual operations toward technologically-driven processes (Zahari & W. Muhamad Radzi, 2021). It allows operational efficiency to flow and ensures the consistent production of high-quality outputs.

For repetitive structural elements, e.g., tunnels, IBS has proven exceptionally effective, with its prevalence leading to tangible results for the national construction industry. Flexible Design for

Manufacturing and Assembly (DfMA) principles are already applied to this process by which economic and technological considerations are incorporated into the design phase, optimising component manufacture and installation and improving quality and competitiveness in a project (Tan et al., 2020). Furthermore, ongoing advancements in raw materials, design solutions, and construction methods reflect the ability of the sector to adopt advanced methodologies.

### *1.3 Strategic Performance Practice of IBS Contractor*

The experts traditionally measure project success through quality, cost, and time measurements. Construction companies are, therefore, constantly deploying new technologies and equipment to optimise these parameters. However, the fragmented sector also undermines IBS supply chain efficiency. Obstacles include incomplete design documentation, lack of understanding of client needs, and poorly performing on-site installation (Zairul, 2021). Accordingly, effective collaboration and communication between stakeholders is essential to integrate design, scheduling, installation, and decision-making processes through the successful implementation of IBS (Riazi et al., 2020).

In Malaysia, IR 4.0 technologies like IoT and BIM are becoming ubiquitous to better safety, communication, productivity and resource utilisation, thereby promoting Sustainable Development goals highlighted in the 11th Malaysia Plan (Roslan, 2022; Taher, 2021). IR 4.0 is a technology integration in developing countries for advanced technologies to give industry actors, skills, and workplace safety at project sites (Roslan, 2022).

The other huge barrier to wider usage of IBS in large scale construction initiatives, is the uncertainty of costs and funding. Robotic technology is very costly, and cost factors are a key barrier to industrial sector adoption of the technology. The purchase and acceptance of such cutting-edge technologies is restricted to enterprises with a considerable fund (Zairul, 2021). Financial limitations in the supply and placement of IBS components often require heavy machinery and capital intensive robotics to procure such components which favours larger firms while excluding small- and medium-sized producers (Irwan Hafizy Md Arif et al., 2020). But the lack of knowledge about IBS often causes the stakeholders to revert to conventional building practices. This issue has worsened in the absence of reliable assessment tools, since those instruments have predominantly paid attention to economic parameters instead of a more detailed scope of project performance variables (Riazi et al., 2020).

The concept is to ensure that IBS is implemented in prefabrication, transport, and installation stages. Delays usually stem from client preferences over on-the-spot casting, dry-mix concrete, poor execution of IBS tasks, and late delivery from suppliers (Al-Awag et al., 2023). In addition, the construction industry, widely recognized as dangerous and labour-intensive, discourages engagement of the local labour market, leading to dependence on foreign labour (Irwan Hafizy Md Arif et al., 2020). The quality of construction may be affected further by conflicts between design and execution divisions (Yunus et al., 2020). As a result, IBS can only be successfully realized when design, logistics, technology and stakeholder interaction are strategically integrated to capitalise on its respective benefits.

## 2. Methodology

Adopting a quantitative cross-sectional research design, this study explored the factors that influence the implementation of the Industrialised Building System (IBS) in government construction projects. A combination of purposive and random sampling was used to assure relevance and represent the diversity of the data. At first, purposive sampling was used by researchers to recruit contractors who are registered with the Construction Industry Development Board (CIDB) Malaysia and have experience in dealing with government building projects using precast concrete. This requirement guaranteed that all participants had appropriate technical and organisational familiarity with various IBS practices. Random sampling was consequently undertaken among this eligible group to control for selection bias and increase generalisability within the defined population.

This study targets IBS contractors working in Selangor, a state known for many IBS projects developed by government in Selangor. While such selective sampling technique enhances internal validity, researchers should take caution in making inferences regarding extrapolation of the findings to contractors working on independent government precast projects outside of precast projects and other geographical settings. This article uses the TOE model to assess technology-organisation-environment (TOE) dimensions of IBS performance by considering how technological capabilities, readiness of the organisation, and the environmental factors are interacting at a contractor level.

### *2.1 Description of Study Area*

Descriptive statistical analysis of the demographic and organisational characteristics of the respondents was applied to the case. Measures of central tendency and dispersion, means and standard deviations were calculated, which were useful to provide a summary of the profile of the sample including company grade, position in the organisation, academic qualifications and experience in IBS projects. This provides supporting context for inferential and structural analyses going forward rather than being representative statistics on their own.

Researchers use a correlational research design to examine the relationships between study variables. The IBS contractors (individual respondents of the survey instrument) were the units of analysis. It is widely accepted in construction management research that data is collected throughout a sample at a single time. By collecting data using a structured questionnaire (structured as such and administered in the natural working environment of the respondents), researchers minimised their intervention which increased the reliability of data and the ecological validity of their findings.

### *2.2 Quantitative Approach*

The study population constituted individuals who were IBS contractors who worked on public construction projects using precast concrete in Selangor. We chose this population because they had relatively higher IBS adoption rates as well as accumulated practical experience, which allowed a more robust assessment of factors affecting the implementation of IBS. The questionnaire was distributed to 120 respondents, with 116 respondents responding to the questionnaires. The team handed out 120 questionnaires in total. After screening, 114 questionnaires were found to be complete and eligible for analysis, a valid response rate of 93%. This clarification addresses a prior inconsistency and guarantees transparency in sample reporting.

Primarily, data were collected through a structured questionnaire format, with minimal clarification after the initial analysis was conducted as needed in order to improve accuracy in responses. This questionnaire aimed at measuring IBS implementation in government construction projects and comprised two parts. Section A collecting respondents' demographics and organisational information, including contractor company grade, job position, academic background, and experience working on IBS projects. Section B operationalised the study constructs by the TOE framework, and involved 50 measurement items divided as follows:

- **Technology construct (17 items)**: concerning construction duration, cost implications, technical complexity, operational challenges associated with IBS implementation.
- **Organisation construct (19 items)**: including 3 sub-constructs, namely organisational resources, organisational productivity and organisational culture, with respect to IBS practices.
- **Environment construct (14 items)**: including three sub-constructs, namely, government policies and incentives, market acceptance of IBS and cleanliness/organisation of the working environment

Every item of the text in Section B was measured by a 5-point Likert scale, meaning participants had to agree on the score from 1 ("Strongly Disagree") to 5 ("Strongly Agree"). The selected measurement items were based on standard research in technology acceptance, construction novelty and IBS deployment to maintain content validity and contextual relevance to the Malaysian building sector.

### *2.3 Quantitative Analysis*

Analysis, data, statistical approach IBM SPSS Version 24.0 and Smart PLS-SEM Version 3.0 were used for data analysis. Preliminary screening and descriptive analysis of the data was done using SPSS, with checks for missing values as well as normal distribution of data. Descriptive statistics were not too long, and it was intentional to focus on main trends that were pertinent to the study (Zeng et al., 2021). Structural Equation Modelling with Partial Least Squares (PLS-SEM) methodology was then used to test the predicted relationships. PLS-SEM was chosen for its applicability for exploratory and theory extension research, its robustness with medium sample sizes, and simultaneous evaluation of measurement and structural models (Hair et al., 2019).

#### 2.3.1 Data Analysis using SPSS

The analyses used to select the sample using IBM SPSS Version 24.0 for initial data analysis with pre-processing of data and its completeness and specificity. Partial information was removed, and descriptive statistics were calculated to report respondent characteristics and general perceptions about IBS practices. Ranking analysis was also conducted by means of mean scores for the most significant IBS-related factors, giving initial hints about IBS-related factors before modelling them structurally.

#### 2.3.2 Data Analysis Using Smart PLS-SEM

Smart PLS-SEM Version 3.0 was used for structural analysis. The PLS-SEM framework has a measurement model that includes an outer model and a structural model. The measurement model looks at the relationships between the latent variables and their measurements to see if they are reliable. The structural model, by contrast, examines the expected connections among the constructs (Hair et al., 2019). Partial Least Squares Structural Equation Modelling (PLS-SEM) is widely accepted as an effective method for analyzing newly developed models. It is especially useful in instances where the available theoretical paradigms or models for explaining new phenomena are small and not extensive enough for the research question and hypothesis (Zeng et al., 2021).

The structural model had been evaluated on three (3) important criteria.

1. **Collinearity Assessment**: Variance Inflation Factor (VIF) values were analysed for multicollinearity; values less than 5 were considered acceptable levels (Hair et al., 2019).
2. **Path Coefficient Assessment**: The significance of the proposed relationship was assessed with standard path coefficients ($\beta$) and bootstrapped t-values. Path coefficients were considered significant when t-values exceeded 1.65 and 2.57 at the 5% and 1% significance levels, respectively (Saleh et al., 2020).
3. **Predictive Accuracy Assessment**: To evaluate the predictive power of the model; we used the coefficient of determination ($R^2$). Substantial predictive accuracy is denoted by an $R^2$ value of 0.75 and above, moderate accuracy by (0.50–0.74) and weak accuracy by (0.25–0.49) (Hair et al., 2019).

## 3. Results and Discussion

### *3.1 Respondent's Profile*

Respondents engaged in IBS construction projects were identified and invited to take part in support of the study objectives. Descriptive frequency analysis was performed to provide an overview of the background characteristics of respondents (e.g.

contractor company grade, organisational position, highest academic qualification, experience in IBS projects). Self-administered web-based questionnaires (email attachment and Google Forms) were distributed to contractors with IBS experience (n = 120). The same platforms were used for receiving completed questionnaires.

A total of 116 responses were obtained from the 120 questionnaires that were distributed. After screening, 114 responses were found complete and valid for analysis, yielding a response rate of 93%, which is reasonable for construction management survey studies. The demographics of the respondents, who had practical experience working on IBS construction projects in Malaysia, are shown in Table 1.

This study sample consisted of contractors involved in precast concrete works in Selangor, a local government area with high incidence of IBS projects. In terms of contractor classification, 76 respondents (67%) were obtained from CIDB Grade G7, while 10 respondents (8.7%) comprised G6 grade. In all, the G5 and G3 had 8 respondents (7.0%) each and G1 and G2 had 5 respondents (4.3%) each. Grade G4 had the lowest percentage, consisting of only two respondents (1.7%). This distribution revealed that most of the respondents came from large and well-established contracting businesses that were extensively engaged in IBS projects. Concerning organisational position, project managers were the biggest group, with 65 respondents (57%) and 44 respondents (39%) from senior engineering or managerial levels. The most limited sample were site supervisors with 5 (4.0%). This profile indicates that most responses were derived from individual members of staff who were involved in planning, decision-making and project implementation.

Most respondents had bachelor's degree (80 respondents, 70%), while a further 24 respondents were master graduated (24 respondents, 21%), and 10 respondents were diploma holding (9.0%). All respondents fell within the pre-specified categories of academic and professional backgrounds, which suggests adequate experience for meaningful IBS implementation assessments. Those with diploma qualifications also provided practical experience, particularly working in the operational management of IBS projects. In the proportion of respondents with IBS experience, the majority (51 respondents) had 1 to 5 years of IBS experience (44.7%), followed by 26 respondents (23%) with 6-10 years, and 22 respondents (19.2%) with more than 15 years. Respondents in the smallest sample had about 11-15 years of experience (15 respondents, 13.1%). It shows that the sample comprised both starting career and advanced practitioners whose professional backgrounds offer a well-rounded view on IBS implementation practices

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**Table 1** Demographic Profile of Respondents

| Demography | Item | 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** | **100%** | |
| Position | Project Manager | 65 | 57% | 57% |
| | Engineer | 44 | 39% | 96% |
| | Site Supervisor | 5 | 4.0% | **100%** |
| | Other | 0 | | |
| | **Total** | **114** | **100%** | |
| Academic | Diploma | 10 | 9.0% | 9% |
| | Bachelor | 80 | 70% | 79% |
| | Master | 24 | 21% | **100%** |
| | PHD | 0 | 0% | |
| | **Total** | **114** | 100% | |
| Experience | 1-5 years | 51 | 44.7% | 44.7% |
| | 6-10 years | 26 | 23% | 67.7% |
| | 11-15 years | 15 | 13.1% | 80.8% |
| | More than 15 years | 22 | 19.2% | **100%** |
| | **Total** | **114** | **100%** | |

Source: Author's Field Survey, 2022

### *3.2 Mean and Standard Deviation Analysis*

Descriptive statistics analysis was used to summarize the respondents' assessments of the determinants of IBS performance. Mean data were used to measure the central tendency of responses representing the perceived importance of the item, and standard deviations to identify how well respondents agreed. Together, the analysis assessed IBS performance determinants along three major aspects, technology, organization, and environment and divided into several criterion factors. Results of the mean and standard deviation analyses are shown in Table 2 and elaborated in the sections to follow.

In the technology dimension, three criteria groups were analysed: time, construction cost, and implementation difficulties. Time items have consistently high means and low standard deviations, indicating a high level of agreement in terms of significance. The challenges group items had moderately high mean values with similarly low dispersion, indicating a consistent assessment of the operational challenges of IBS practices. On the organisation dimension, three criterion groups were evaluated: organisational resources, productivity, and social–cultural. However, the findings showed a perception that social-cultural are important, indicated by high mean values and low standard deviation of the items.

A similar pattern was manifested for items related to productivity, indicating strong agreement as to the extent to which these factors helped effective IBS implementation. Organisational resources variables showed moderately high average values and lower dispersion, which implied that respondents perceived their positive contribution of helping IBS performance as consistent. For the environment dimension, three criteria-group analyses were conducted, which were government policies, market popularity, and working environment cleanliness. The high mean values with small standard deviation for market popularity related items were consistent with the key role that the successful implementation of IBS.

In a similar vein, the popularity group had consistently high but variation-free mean scores, indicating uniform assessments of market acceptance and innovation-related factors. The clean environment group had moderate high mean values with small standard deviations, which means that the respondents tend to agree well on the importance of site organisation, material delivery process, waste management process, and operational reliability. With some items indicating a slightly higher standard deviation, the range was acceptable and did not contribute to the variation and consistency of results.

**Table 2** Descriptive measure

| Construct | Sub-Construct | Mean | Standard | Ranking | Overall Mean | Overall Ranking |
|---|---|---|---|---|---|---|
| Technology | T 01 | 4.37 | 0.875 | 1 | 4.32 | 1 |
| | T 02 | 4.23 | 0.855 | 2 | | |
| | T 03 | 4.37 | 0.876 | 1 | | |
| | CO 01 | 3.93 | 0.965 | 1 | 4.04 | 9 |
| | CO 02 | 4.29 | 0.872 | 1 | | |
| | CO 03 | 3.89 | 0.962 | 4 | | |
| | CO 04 | 4.07 | 0.913 | 2 | | |
| | C 01 | 3.62 | 1.054 | 10 | 4.06 | 7 |
| | C 02 | 3.78 | 1.103 | 9 | | |
| | C 03 | 4.08 | 0.898 | 5 | | |
| | C 04 | 4.28 | 0.814 | 3 | | |
| | C 05 | 4.44 | 0.909 | 2 | | |
| | C 06 | 3.89 | 1.007 | 7 | | |
| | C 07 | 4.23 | 0.834 | 4 | | |
| | C 08 | 4.04 | 0.934 | 6 | | |
| | C 09 | 3.81 | 0.948 | 8 | | |
| | C 10 | 4.45 | 0.705 | 1 | | |
| Organization | OR 01 | 4.22 | 0.903 | 1 | 4.05 | 8 |
| | OR 02 | 4.17 | 0.755 | 2 | | |
| | OR 03 | 3.90 | 0.949 | 5 | | |
| | OR 04 | 4.02 | 0.846 | 3 | | |
| | OR 05 | 3.95 | 0.981 | 4 | | |
| | P 01 | 4.30 | 0.754 | 1 | 4.13 | 6 |
| | P 02 | 4.14 | 0.851 | 3 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | P 03 | 4.10 | 0.802 | 4 | | |
| | P 04 | 4.02 | 0.846 | 5 | | |
| | P 05 | 4.02 | 0.814 | 5 | | |
| | P 06 | 4.18 | 0.804 | 2 | | |
| | SF 01 | 4.22 | 0.624 | 5 | 4.21 | 3 |
| | SF 02 | 3.94 | 1.046 | 8 | | |
| | SF 03 | 4.33 | 0.724 | 3 | | |
| | SF 04 | 4.36 | 0.778 | 2 | | |
| | SF 05 | 4.21 | 0.761 | 6 | | |
| | SF 06 | 4.00 | 0.836 | 7 | | |
| | SF 07 | 4.25 | 0.662 | 4 | | |
| | SF 08 | 4.37 | 0.670 | 1 | | |
| Environment | GP 01 | 4.15 | 0.888 | 3 | 4.15 | 5 |
| | GP 02 | 3.99 | 0.963 | 5 | | |
| | GP 03 | 3.90 | 0.921 | 6 | | |
| | GP 04 | 4.42 | 0.676 | 1 | | |
| | GP 05 | 4.13 | 0.964 | 4 | | |
| | GP 06 | 4.29 | 0.727 | 2 | | |
| | PL 01 | 4.33 | 0.760 | 2 | 4.31 | 2 |
| | PL 02 | 4.21 | 0.867 | 3 | | |
| | PL 03 | 4.41 | 0.726 | 1 | | |
| | CE 01 | 4.28 | 0.848 | 2 | 4.17 | 4 |
| | CE 02 | 3.88 | 1.070 | 5 | | |
| | CE 03 | 4.39 | 0.805 | 1 | | |
| | CE 04 | 4.11 | 0.984 | 4 | | |
| | CE 05 | 4.23 | 0.779 | 3 | | |

Source: Author's Field Survey, 2022

## *3.3 Analysis Structural Model*

To evaluate the hypotheses of the relationships between the study constructs, the structural model was constructed. The proposed paths were assessed with Smart PLS-SEM for the direction of the associations, their strength, and statistical significance. There were four essential procedures for evaluating the structural model: (i) assessment of collinearity, (ii) evaluation of the significance and strength of path relationships, (iii) assessment of the predictive power of the model, and (iv) examination of effect sizes. Taken together, these procedures compute the model's explanatory power regarding variance of endogenous constructs.

### 3.3.1 Collinearity Analysis

As a first step to see if each predictor construct was contributing uniquely to the model, the collinearity assessment was performed. The VIF values for all predictor constructs technology, organisation, and environment were analysed. All the VIF values were less than the recommended threshold of 5 and no multicollinearity problems were encountered. This indicates clear separation of constructs and validation of structural model estimations for testing in future with Smart PLS-SEM (Table 3).

**Table 3** Collinearity Analysis

| Construct | VIF |
|---|---|
| Organization | 2.024 |
| Environment | 2.161 |
| Technology | 1.875 |

#### 3.3.2 Assessing the strength and Significance of Structural Relationships

To assessed the strength and significance of the hypothesised relations (path coefficients (β)) based on the structural model. Not only do these coefficients indicate the direction but also the magnitude of relationships between the exogenous constructs and IBS performance. Using t-statistics and p-values calculated using a bootstrapping procedure, with 5,000 resamples, to determine statistical significance as indicated (Hair et al., 2019). path coefficient within acceptable limits of significance serves to provide empirical evidence to support the candidate hypothesis. Three hypotheses were tested in this study:

H1: Organisation has a significant relationship with IBS performance.
H2: Environment has a significant relationship with IBS performance.
H3: Technology has a significant relationship with IBS performance.
Standardised path coefficients vary from −1 to +1, and larger absolute value indicated stronger effects (Hamdollah & Baghaei, 2016). The large β is the strongest predictive factor of IBS performance. Hence, higher β scores imply greater explanatory contribution to IBS performance. The outcome of path coefficient analysis is displayed in Table 4. Evidence suggests organisational factors have a positive, statistically significant effect on IBS performance ($\beta = 0.368$, $t = 3.759$, $p < 0.05$), supporting H1. By contrast, environmental variables have a weak, non-significant correlation with IBS performance, ($\beta = 0.086$, $t = 0.855$, $p > 0.05$) leading to the rejection of H2. As technology-related factors show the strongest and most significant positive effect on IBS performance ($\beta = 0.471$, $t = 5.673$, $p < 0.005$), thus supporting H3.
Based on findings in Table 4, technology emerges as the most significant determinant of IBS performance, followed by organizational factors, while environmental factors lack statistical significance. In line with PLS-SEM methodology, the path coefficients reflect the relative contribution of each predictor to explaining variations in IBS performance (Hair et al., 2019). At the conventional statistical significance level $p < 0.05$, only technology and organisational factors are significantly associated with variations in IBS performance.

Considering the negligible contribution of environmental factors in the results, it reveals that, even though government policies, market popularity and site environment conditions exist, they are not the major drivers of effective implementation of the IBS. This means that IBS implementation in government projects is perceived as a technical and organisational obligatory rather than an intervention based on external influences. Moreover, with government incentives and promotion measures even in existence, such readiness and execution of IBS procedures remain limited, leading to the perception that environmental support alone will not improve IBS performance much without significant technological capability and organisational capacity.

**Table 4** Relationships between Variables

| Hypothesis | Relationship | Original Sample (β) | Standard Deviation | Statistic (*t*) | Value (*p*) | Decision |
|---|---|---|---|---|---|---|
| H1 | Organization>Performance IBS | 0.368 | 0.098 | 3.759 | 0.00 | Supported |
| H2 | Environment>Performance IBS | 0.086 | 0.101 | 0.855 | 0.19 | Not Supported |
| H3 | Technology>Performance IBS | 0.471 | 0.083 | 5.673 | 0.00 | Supported |

Note: A relationship is considered statistically significant when $P<0.05 (t>1.96)$

#### 3.3.3 Assessing the Predictive Power of the Model

The performance of the structural model was assessed via the coefficient of determination ($R^2$), which reflects the variability in the endogenous construct explained by the exogenous predictors. Greater $R^2$ values reflect better predictability(Hair et al., 2019). The explanatory power of the model is presented in Table 5. The results show the $R^2$ was 0.670, above the moderate value of 0.50 recommended by (Sarstedt et al., 2022). This finding suggests that the model has considerable predictive properties. In particular, the results indicate that 67% of the variance in IBS performance is explained jointly by technological, organisational, and environmental determinants. By comparison, 33% is due to variables that are not represented in the current analysis. These findings indicate strong explanatory capacity of the model while also highlighting the potential relevance of additional determinants, such as project-specific characteristics or stakeholder-related factors, for future investigation.

**Table 5** Predictive accuracy value of the model

| Construct | $R^2$ | $R^2$ Adjusted | Level |
|---|---|---|---|
| IBS Performance | 0.670 | 0.661 | Substantial |

Source: Author" s Field Survey, 2022

### 3.3.4 Effect Sizes

The effect size ($f^2$) was estimated for each exogenous construct's contribution to the endogenous variable. The effect size analysis assesses the influence of a given predictor's omission from the model on the change in the coefficient of determination ($R^2$), reflecting the practical importance of that predictor(Hair et al., 2019). Larger $f^2$ values indicate a greater influence of the exogenous construct on the explained variance of the endogenous construct.

According to recommended results, $f^2$ coefficients of 0.35, 0.15, and 0.02 mean a large, medium, and minor effect, respectively. Values < 0.02 imply negligible influence. Table 6 shows results of effect size analysis. The results show that technology significantly affects IBS performance ($f^2$ = 0.358), indicating that technology plays a dominant role in explaining performance variation. Organisational factors show a medium effect ($f^2$ = 0.203) showing a significant, albeit smaller, contribution.

However, environmental factors have a negligible effect ($f^2$ = 0.010), indicating a minimal contribution of environmental variables on the $R^2$ value of IBS performance. Collectively, the effect size results support the structural path finding that technology is the highest predictor of IBS performance, while organisational factors are next. On the other hand, the environmental aspects have a limited practical effect within the proposed model.

**Table 6** Effect Sizes

| Exogenous Construct | $f^2$ values | Effect Sizes |
|---|---|---|
| Organization | 0.203 | Medium |
| Environment | 0.010 | Small |
| Technology | 0.308 | Large |

Note: $f^2$ > 0.35 = Large; 0.15–0.35 = Medium; 0.02–0.15 = Small; <0.02 = No effect

## 4. Discussion

The discussion could be improved by a better correlation between study results and previous studies. The results of this study present evidence that the effect of technology on IBS performance is significant and confirms the need for innovative construction practices and system integration to realize IBS effectiveness. Within the TOE framework, technological ability is the key driver for IBS performance, however technology is not adequate without associated organisational support.

It is interesting to note the strength of the technology's influence only when it is leveraged with a high level of organisation capability. Management commitment, skilled workforce and coordination among design, manufacturing and site team's moderate impact. This is consistent with previous studies suggesting that organisational preparedness is critical, determining whether technology investments convert into measurable performance benefits (MOF, 2020; Zairul, 2021).
However, with the available and unused technology, in practice, weak organisational capacity may hinder the best use of IBS technologies, thereby limiting potential rewards.

A descriptive analysis revealed that construction cost made up the most excellent mean value (4.32) of time, follow by popularity of IBS (4.32) and low mean value construction cost (4.04). Upfront expenses, lack of competencies, and limited resources remain major obstacles due to previous literature. Although IBS has the potential to minimise waste, enhance quality, and speed up projects, such challenges may limit its benefits in cases where organisational and technical resources are not available.
Environmental influences on IBS performance were notable. Although government policies and regulatory support play a significant role in facilitating IBS uptake in Malaysia, the impact is found to be insignificant. This could indicate a disparity between policymaking and implementation on projects, wherein ensuring regulatory compliance is not necessarily correlated with improved operational performance.

Simply placing pressure on the environment is not enough according to TOE, as without organisational readiness and technology capability, the pressure on external environments will not be adequate. It offers a strong predictive power as the measure has a coefficient of determination ($R^2$ = 0.670), suggesting that the constructs used in this model represent a meaningful fraction of variance in IBS performance. Reliability and validity were tested for composite reliability, average variance extracted, and discriminant validity measures, which met the recommended levels and strengthened the measurement model.

These results coincide with previous studies using PLS-SEM and TOE analysis packages to investigate the implementation of IBS in government construction projects. Although the Malaysian IBS ecosystem is embedded in an integrated system of policies technologies, the challenges of organizational capacity, cost, and expertise in practical use are still a stumbling block to the highest level of IBS performance. These gaps indicate a need for strategies to bolster organizational readiness and assimilate technological innovation – a roadmap to enhanced IBS use and performance on the real construction sites.

## 5. Implication

### *5.1 Theoretical and Practical Implications*

The findings support technology as the core driver of IBS performance, which is in line with the Technology–Organisation–Environment (TOE) model. Technology serves as the engine that drives productivity and efficiency within organisations and the management of projects. Automation, digital design tools, prefabrication systems and advanced technologies allow for systems-based planning, effective coordination as well as optimal coordination in designing, manufacturing and assembly works.

These features help reduce design errors, minimize material waste, and enhance production efficiency and quality in IBS projects. Second, technology enhances integration throughout the IBS value chain. Information management systems to track production schedules, logistics, and site installation streamline facility to site coordination and minimize delays and setbacks. Technology capability from a sustainability viewpoint helps to save time and resources on material and avoid project waste with higher productivity. Add-ons together, these findings collectively posit technology as a powerful tool for supporting high-performance IBS practices and the IBS, situating IBS development within a more integrated Industry 4.0 vision for the construction industry.

### *5.2 Implications for the Industry (Contractors, CIDB, Policy Makers)*

For industry stakeholders, the findings suggest that strengthening IBS infrastructure requires enhanced policies and implementation mechanisms that prioritize technological adoption. The Construction Industry Development Board (CIDB) might also strengthen current IBS scoring systems by incorporating criteria for digital capability such as BIM adoption, automation, and advanced prefabrication technologies. At the same time, CIDB can act as a booster as practitioners and academic institutions and tech providers begin to cooperate more closely to fasten IBS innovation and capacity building.

For contractors, such results underline the necessity of technological capability investment for enhancing productivity, quality, and sustainability performance in IBS projects. These types of investments are necessary to deliver the performance specifications of the largest government projects and to be competitive in a technology-enabled construction sector.

From the view of the Public Works Department (JKR), as the leading implementing agency responsible for the implementation of government infrastructure construction projects, the results imply the necessity for a systemic implementation of IBS technologies into procurement strategies and project management frameworks. This includes the alignment of contractor selection criteria, project specifications, and performance monitoring to technological readiness and organisational capability.
Through this study, it illustrates how the performance of IBS must ensure a coordinated engagement of the CIDB as policymaker, the contractors as implementers, and the JKR as the project owner and manager. Such alignment will be needed across the board to ensure that IBS practices are not just mandated, but digitally enabled, organisationally supported, and sustainably implemented.

## 6. Conclusion

Through this study, we provide both theoretical and operational contributions to the study of Malaysian construction industry adoption and performance of the Industrialised Building System (IBS).

### *6.1 Theoretical Implications*

The study contributes to the IBS literature by enhancing the understanding of the determinants behind contractors' IBS performance. Results demonstrate the benefits of a holistic view with a focus on technological, organisational, and human resource considerations. The work supports the significance of the Technology–Organisation–Environment (TOE) model to show that technological capabilities and organisational readiness are central to IBS effectiveness. The associations of these determinants with IBS performance provide insight that enhances current theoretical knowledge and contributes to the formulation of a more theoretically rooted model of IBS take-up.

### *6.2 Practical Implications*

From an applied perspective, this paper will give policymakers in construction, contractors, and all parties involved in the area. According to the findings, the adoption of IBS should be broadened to encompass a range more than just precast concrete; if only this can be done in full-scale, so we get the full efficiency, productivity and quality benefits. The implementation of digital solutions such as Building Information Modelling (BIM), robotics, automation, standardised design, and project monitoring systems is crucial in improving project management and efficiency. In addition, organisations such as the Construction Industry Development Board (CIDB) and the

Public Works Department (JKR) contribute significantly to improving IBS training and developing technical skills for improving the work experience and lessening the reliance on the use of foreign labour.

### *6.3 Future Research Directions*

It is essential to extend the project scope of possible future research towards all IBS systems in Malaysia, leading to a broader evaluation of operational efficiency across different types of projects. Research could also investigate the impact of digital technologies on Industry 4.0 agenda, particularly on the support for integration of Industry 4.0. Moreover, it would be very useful to carry out empirical analyses of existing workforce competencies as well as the extent to which training programs are effective in the context of IBS performance and long-term sustainable development of the construction industry.

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## Conflicts of Interests

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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