

Overcoming Barriers to Industrialized Building System (IBS) Adoption Through BIM-Enabled Cost Optimization in Malaysian Construction Projects

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ABSTRACT

The integration of Industrialized Building Systems (IBS) and Building Information Modelling (BIM) represents a pivotal advancement in transforming conventional construction practices towards industrialization. Despite the increasing promotion of IBS under Malaysia's Construction Industry Transformation Programme (CITP 2016–2020), its implementation continues to face challenges arising from fragmented project delivery methods, limited coordination, and poor planning. Concurrently, BIM offers significant capabilities to address these issues through digital collaboration, real-time information management, and design visualization. This paper explores the development of an IBS–BIM integrated framework aimed at enhancing productivity, efficiency, and sustainability in the Malaysian construction industry. A comprehensive literature review was conducted to identify the impacts of IBS–BIM integration, followed by a quantitative survey using structured questionnaires among key industry stakeholders—including architects, engineers, quantity surveyors, and project managers—supplemented by qualitative validation through expert focus group discussions. The findings reveal that the synergy between IBS and BIM mitigates major industry barriers, such as coordination gaps, rework, and design inconsistencies, while fostering collaboration, accuracy, and cost efficiency across project stages.

Keywords— Industrialized Building System (IBS), Building Information Modelling (BIM), construction industrialization, productivity, Malaysia

INTRODUCTION

The construction sector in Malaysia plays a vital role in national development but continues to struggle with low productivity, inefficient project delivery, and reliance on traditional methods. IBS has become an important tool that potentially boosts the construction industry's productivity. The main essential characteristic of IBS is its construction components that are prefabricated and manufactured in a controlled environment to be assembled into structures with minimal site works. IBS emerged as a government-endorsed solution to industrialize the sector through prefabrication and modular construction. Despite its advantages, IBS projects often face setbacks due to poor coordination, inadequate planning, and weak integration between design and execution. BIM, a technology for digital modeling and data management, has been increasingly promoted as a complementary solution to overcome these issues. When implemented jointly, BIM and IBS have the potential to enhance design precision, reduce on-site errors, optimize logistics, and improve lifecycle management. This paper proposes a framework for integrating BIM and IBS into construction projects to maximize efficiency, reduce waste, and ensure sustainable outcomes.

Problem Statement

Both IBS and BIM are actively championed by the Malaysian government through strategic initiatives such as the Construction Industry Transformation Programme (CITP) 2016-2020, the National Construction Policy (NCP) 2021-2025, and the Construction 4.0 Strategic Plan 2021-2025. These policies are designed to enhance the overall performance and efficiency of the industry through the strategic adoption of advanced technologies.

Despite the Malaysian government's continuous push for IBS adoption and the growing relevance of BIM, the integration of these two systems remains fragmented and underutilized. According to Woo & Penial (2021)¹⁸ the implementation of BIM in IBS is relatively low since IBS contractors in Malaysia has difficulties such as technical problems, management, environmental issues, financial problems and legal issues in implementing BIM in IBS construction project. BIM advantages are also not fully realized in IBS design processes.

Research Aim and Objectives

The aim of this research is to develop an IBS-BIM integrated framework towards enhancing construction efficiency in Malaysia. The objectives of this research are to:

1. Identify the impacts of IBS-BIM integration towards industrializing construction in Malaysia
2. Determine the integrated IBS and BIM Approach required to manage industrialization in construction projects
3. Recommend a framework for evaluating the influence of the IBS - BIM approach in managing industrialization for construction projects

LITERATURE REVIEW

Overview of IBS and BIM in the Construction Industry

The construction industry is undergoing a paradigm shift from traditional labor-intensive practices to technologically integrated and industrialized methods. The Industrialized Building System (IBS) is central to this transformation, defined as a construction process involving prefabrication of building components in a controlled environment, followed by on-site assembly. IBS contributes to enhanced productivity, quality control, and sustainability, while also reducing material waste and dependence on unskilled labor (Mydin, 2014; Kamar et al., 2009). Despite these advantages, the adoption of IBS in Malaysia has been slow due to fragmented project delivery, high initial capital requirements, and inadequate technical expertise among industry players (Mohd Nawawi et al., 2016).

Conversely, Building Information Modelling (BIM) has gained global recognition as an enabler of digital transformation within the built environment. BIM is a process-driven approach that utilizes intelligent 3D models embedded with parametric data, allowing collaboration and information sharing among project participants throughout the lifecycle of a facility (Na Lu & Korman, 2010). The integration of time (4D) and cost (5D) dimensions further supports project simulation, enabling precise visualization, coordination, and decision-making (Shrutiniwas Sharma et al., 2017). As such, BIM provides an efficient platform for design optimization, risk management, and real-time data synchronization.

Challenges of IBS Implementation in Malaysia

Although IBS has been promoted since the 1960s as a solution to Malaysia's housing demand, several persistent challenges hinder its widespread adoption. These include:

1. Financial constraints: High initial investment in manufacturing facilities, machinery, and molds makes IBS less attractive to small and medium-sized contractors (Jabar et al., 2013; Amin et al., 2017).
2. Lack of expertise: Limited knowledge among designers and contractors on IBS design, modular coordination, and standardization leads to operational inefficiencies (Abdullah et al., 2021).
3. Coordination issues: Ineffective collaboration between stakeholders during design and fabrication results in design conflicts, transportation delays, and reworks (Fitri Othman et al., 2017).
4. Resistance to change: The construction workforce's dependence on traditional methods and foreign labor discourages the transition to industrialized approaches (Amin et al., 2017).

The cumulative impact of these factors manifests as project delays, excessive costs, and underutilization of IBS technology, ultimately limiting the industry's capacity to achieve CIP productivity targets.

BIM Capabilities in Addressing Construction Inefficiencies

BIM provides a collaborative digital environment where project data is created, managed, and shared seamlessly. In the context of IBS implementation, BIM can address fragmentation and inefficiencies through several mechanisms:

1. Enhanced collaboration: BIM facilitates multi-disciplinary coordination among architects, engineers, and contractors, reducing design errors and information gaps (Yan & Damian, 2008).
2. Clash detection: The system identifies conflicts between structural, mechanical, and electrical components before physical construction begins, minimizing costly rework (Becerik-Gerber & Rice, 2010).
3. Cost and time optimization: The integration of cost and scheduling data within the BIM model improves resource planning, reducing waste and improving financial predictability (Zhang & Gao, 2013).
4. Lifecycle management: BIM extends its utility beyond construction to include operation and maintenance, ensuring long-term asset performance (AlabdulQader et al., 2013).

In Malaysia, public sector initiatives such as the Public Works Department (PWD) BIM Roadmap and CIDB BIM Guidelines (2013) have catalyzed adoption. However, implementation remains in early stages, particularly in small-scale private projects.

Synergizing IBS and BIM

The convergence of IBS and BIM represents a strategic solution to industrialize construction practices. Integrating the two systems ensures continuity of information from design to fabrication, aligning with the objectives of lean construction and sustainable development. BIM assists in modeling precise geometries for prefabricated IBS components, enabling off-site manufacturing with minimal errors (Linga, 2015). Moreover, BIM simulations optimize logistics, crane operations, and installation sequencing, improving site safety and reducing idle time (Volkan Ezcan et al., 2013). The integration also enhances aesthetic flexibility, allowing designers to explore alternative design options while maintaining constructability and cost efficiency.

Na Lu and Korman (2010) emphasize that BIM-based coordination of Mechanical, Electrical, and Plumbing (MEP) systems is particularly beneficial in IBS projects, where spatial and tolerance constraints are critical. Furthermore, BIM integration aids in managing transportation risks and modular assembly, thereby improving project delivery reliability. Building Information Modelling (BIM) is defined as the creation and sharing of an intelligent, computable three-dimensional (3D) data set among various professionals, supporting virtual simulation and modification of design parameters. BIM technology clarifies the fragmentation concerns endemic to the industry.

Crucially, BIM extends beyond spatial modeling (3D) to connect the entire design and documentation process with the dimensions of time (4D) and cost (5D) (Shrutiniwas Sharma et al., 2017). This capability allows stakeholders to virtually simulate the entire construction process, enabling experimentation and optimization before any physical commitment occurs. BIM is recognized for its potential to reduce reworks and errors, enhance collaboration and communication, and improve accuracy and overall project quality (Abdullah et al., 2021).

Previous Frameworks and Research Gaps

Previous research has explored BIM or IBS independently, but comprehensive frameworks integrating both technologies remain limited in Malaysia. Studies by Hamzah et al. (2016) and Mohd Nawi et al. (2014) highlighted BIM's capacity to reduce fragmentation yet did not establish a structured framework for integration. Similarly, IBS research has focused on productivity and sustainability outcomes without addressing the role of digital coordination. Consequently, this gap necessitates the development of a holistic IBS–BIM integrated framework that supports decision-making, standardization, and technological alignment in the Malaysian construction sector.

RESEARCH METHODOLOGY

This study adopts a mixed-method research design, combining quantitative and qualitative approaches to achieve a comprehensive understanding of the integration between Industrialized Building Systems (IBS) and Building Information Modelling (BIM). The design comprises four sequential stages: (1) contextual literature review, (2) framework development, (3) framework verification, and (4) analysis and discussion. This structure ensures that empirical findings are grounded in theory and validated by industry expertise, thereby enhancing both academic rigor and practical applicability.

Stage 1: Contextual Literature Review

The first stage involved an extensive literature review focusing on the current state of IBS and BIM implementation in Malaysia and internationally. Academic journals, industry reports, and official publications from the Construction Industry Development Board (CIDB) were reviewed to identify key issues, impacts, and integration opportunities. Literature published within the most recent ten-year period (2015–2025) was prioritized to ensure contemporary relevance, except for foundational works addressing theoretical concepts. The synthesis of these studies enabled the identification of variables and indicators forming the theoretical basis for the IBS–BIM integrated framework.

Stage 2: Framework Development

In the second stage, a quantitative survey was conducted to obtain empirical data on the perceptions and experiences of construction professionals regarding IBS–BIM integration. A structured questionnaire was developed based on the theoretical framework derived from the literature review. The instrument included closed-ended questions designed to measure respondents' awareness, readiness, perceived impacts, and perceived barriers to IBS–BIM adoption.

The survey targeted key stakeholders within Malaysia's construction industry, including architects, civil engineers, quantity surveyors, project managers, and contractors. All participants were registered under their respective professional bodies—such as the Board of Architects Malaysia (LAM), Board of Quantity Surveyors Malaysia (BQSM), and Board of Engineers Malaysia (BEM)—ensuring data reliability. Systematic random sampling was employed, focusing on respondents operating within the Klang Valley, where IBS and BIM adoption are most active. Sample size determination followed the approach proposed by Krejcie and Morgan (1970), ensuring a representative and statistically valid sample.

Stage 3: Framework Verification

Following the quantitative phase, the proposed IBS–BIM framework underwent qualitative verification through focus group discussions (FGD). The FGD consisted of 8–10 expert panel members drawn from academia, government agencies, and private-sector firms actively engaged in BIM and IBS implementation. Participants were selected based on professional experience exceeding ten years in construction project management or technology integration.

Stage 4: Final Analysis and Synthesis

The final stage integrated the results of both the quantitative and qualitative analyses. This triangulated approach allowed for the identification of converging evidence and provided a comprehensive understanding of IBS–BIM integration dynamics. Comparative analysis was conducted between empirical findings and previous research to establish consistency, validity, and originality. The refined framework was then finalized as a conceptual and practical tool for evaluating industrialization in construction projects.

Data Analysis And Findings

The study examines all aspects of the IBS-BIM method, including its impact on project management, cost efficiency, time savings, and overall construction quality. By leveraging statistical analysis and stakeholder feedback, we seek to uncover the practical implications of adopting this integrated framework in the

construction sector. The findings of this study highlight that the integration of Industrialized Building Systems (IBS) and Building Information Modelling (BIM) holds transformative potential for advancing construction industrialization in Malaysia. A total of 222 respondents had completed the survey. And most of the respondents had working experience for more than 5 years.

This section will be divided into three sections, that cover major aspects of the research findings:

Identify the impacts of IBS-BIM integration towards industrializing construction in Malaysia

The quantitative assessment confirms that the most highly perceived benefits cluster around collaboration, design accuracy, and cost predictability. The table below outlines the top-ranked impacts derived from practitioner surveys:

Table 1: Ranked Impacts of IBS-BIM Integration on Construction Industrialization

Rank	IBS-BIM Impact Statement	Mean Score	Primary Benefit Category
1	BIM results in improved data sharing, increased cooperation, and efficient delivery of design details.	3.89	Collaboration/Communication
2	BIM can improve the entire IBS design process by giving a visual representation of the design.	3.89	Quality/Design
3	BIM facilitates a more comprehensive understanding of the project's parameters, allowing for accurate cost estimations and assessments of the construction timeline (5D).	3.86	Cost/Efficiency (5D)
4	BIM helps identify conflicts within the process, effectively plan resources, optimize construction site layouts, and detect discrepancies.	3.85	Clash Detection/4D Planning
5	Building Information Modelling (BIM) aims to reduce IBS inefficiencies.	3.69	Strategic Alignment

The strongest perceived benefit (Rank 1) is improved data sharing and enhanced cooperation. This highlights that BIM's greatest immediate contribution is its ability to overcome the foundational fragmentation barrier, thereby enabling the downstream benefits like 5D cost estimation (Rank 3) and efficient clash detection (Rank 4).

Determine the integrated IBS and BIM Approach required to manage industrialization in construction projects.

The successful management of industrialization requires addressing technological, human, and regulatory gaps, necessitating specific, strategically prioritized integrated approaches:

Table 2: Integrated IBS-BIM Approaches Required to Manage Industrialization

Rank	Integrated Approach Strategy	Mean Score	Implementation Focus
1	Ensure standardized data formats between BIM and IBS systems.	3.99	Data Governance / Interoperable

2	Training and Skill enhancement; offer project teams BIM and IBS technology training.	3.95	Human Capital Development
3	Utilizing 3D data visualization of BIM for automatic conversion of architectural plans, schedules, and budget estimation.	3.91	Technology Application (5D)
4	Endorse policy and regulatory guidance that fosters BIM and IBS integration.	3.84	Policy/Enforcement
5	Enhance construction efficiency by employing BIM for on-site logistic planning and assembly sequencing	3.85	Planning

The fact that Standardized Data Formats (Mean 3.9910) ranks highest emphasizes that integration is fundamentally a data governance challenge. BIM cannot reliably deliver 5D cost optimization if data exchange between the design model and factory fabrication systems is not seamless and interoperable. Closely following (Rank 2) is the need for dedicated training and skill enhancement. This addresses the lack of local IBS expertise and mitigates organizational reluctance by building internal competency.

Recommend a framework for evaluating the influence of the IBS - BIM approach in managing industrialization for construction projects

The proposed framework integrates technological standards, process maturity, and measurable economic performance across the project lifecycle. The structure is built upon empirically validated evaluation factors, ensuring that adoption is not merely compliance, but a strategic pursuit of performance enhancement.

Table 3: Framework Components for Evaluating IBS-BIM Influence on Project Performance

Evaluation Component	Rank	Focus Area	Key Metric/Action
Continuous Improvement	1	Process Refinement	Set up processes for ongoing IBS-BIM implementation improvement, addressing practical skepticism.
Technology Interoperability	2	Foundational Success	Ensure IBS and BIM technologies are compatible and interoperable (data formats).
Cost and Time Efficiency	3	Economic Viability (5D)	Calculate the cost and time savings resulting from the IBS-BIM approach, comparing to conventional baselines.
Quality and Safety	4	Product Integrity	Evaluate how IBS-BIM affects the safety and quality of construction (e.g., defect rates).
Regulatory Compliance	5	Policy Adherence	Verify that the IBS-BIM methodology conforms with national/international building codes.

The framework mandates that the economic benefits be rigorously quantified. The calculation of cost and time savings resulting from the integrated IBS-BIM approach (Rank 3) is essential for stakeholders to evaluate their overall project and financial performance against conventional construction baselines. This quantitative validation provides the necessary justification for the high initial investment in IBS and BIM technology.

CONCLUSION

The integration of Industrialized Building Systems (IBS) and Building Information Modelling (BIM) represents a pivotal step toward industrializing Malaysia's construction sector. This study has demonstrated

that the synergy between these two technologies offers a transformative pathway for overcoming long-standing inefficiencies associated with traditional construction methods. By aligning digital design with prefabricated production processes, IBS–BIM integration enables higher productivity, improved collaboration, and enhanced sustainability across all project stages.

The findings reaffirm that fragmented communication, inconsistent data management, and lack of coordination are the key inhibitors of IBS implementation in Malaysia. BIM, through its comprehensive visualization, data integration, and real-time collaboration features, effectively mitigates these challenges. Empirical results derived from quantitative and qualitative analyses confirm that the integration of IBS and BIM improves cost efficiency, reduces construction duration, enhances quality, and facilitates better decision-making.

Furthermore, the developed IBS–BIM integrated framework provides a systematic approach for assessing and managing industrialization performance in construction projects. It encompasses three core dimensions—technological integration, process coordination, and performance outcomes—each of which contributes to optimizing productivity and competitiveness. The framework aligns with Malaysia's Construction Industry Transformation Programme (CITP), Industry 4.0 (IR4.0) vision, and Sustainable Development Goals (SDG 17) BY supporting digitalization, innovation, and sustainable growth in the built environment.

RECOMMENDATIONS

To further enhance the practical implementation of IBS–BIM integration, several key recommendations are proposed:

Strengthening Policy and Regulatory Support

The Malaysian government, through agencies such as CIDB and PWD, should establish comprehensive policies that mandate the adoption of BIM in all public and large-scale private projects employing IBS. National standards for BIM interoperability, data exchange, and digital workflows should be formulated to ensure consistency and compliance across the construction sector.

Capacity Building and Training

Continuous professional development is critical to equipping industry practitioners with the technical and managerial competencies required for IBS–BIM integration. Training modules, certification programs, and university curricula should emphasize digital construction skills, modular coordination, and collaborative project delivery models.

Investment in Technological Infrastructure

Stakeholders should allocate resources to upgrade hardware, software, and data management systems to facilitate seamless integration of BIM with IBS manufacturing processes. Financial incentives or tax benefits could be introduced to encourage small and medium-sized enterprises (SMEs) to adopt digital construction technologies.

Encourage Collaborative Project Delivery

Integrated Project Delivery (IPD) and Design-Build (DB) approaches should be promoted to foster early collaboration among architects, engineers, manufacturers, and contractors. Such collaborative environments enable concurrent design, fabrication, and construction, aligning with the efficiency principles of industrialization.

Future Research Directions

While this study provides a foundational framework for IBS–BIM integration, future research should focus on longitudinal case studies to measure the long-term impacts of implementation across different project types. Additional exploration into Artificial Intelligence (AI), Internet of Things (IoT), and Digital Twin technologies

could further enhance the predictive and adaptive capabilities of the framework, aligning with emerging Industry 4.0 paradigms.

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