

Building Information Modeling (BIM) Implementation Strategies In The Construction Industry: A Comprehensive Review Of Roles, Challenges, And Frameworks

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ABSTRACT

Abstract: Building Information Modelling (BIM) has transformed the construction sector through digital integration that enhances efficiency, collaboration, and data management. This study synthesizes findings from four key publications to provide an overview of BIM implementation methods and challenges across different contexts. The review covers: (1) the development of a BIM implementation framework for structural engineering firms based on Critical Success Factors (CSFs) to address organizational and technical barriers; (2) the essential role of the BIM Manager in maintaining data quality, coordinating multidisciplinary teams, and ensuring software interoperability; (3) specific challenges in applying BIM to infrastructure projects, particularly the need for universal data standards and robust information governance; and (4) barriers to BIM adoption in prefabricated construction, including limited stakeholder coordination and regulatory gaps. Overall, the findings highlight that successful BIM implementation depends not only on technology, but also on organizational readiness, human resource competence, supportive regulations, and structured collaboration. This article concludes with strategic recommendations to optimize BIM implementation for improved design accuracy, construction efficiency, and project sustainability.

Keywords: BIM, Implementation, BIM Manager, Interoperability, Multidisciplinary Collaboration, Prefabricated Construction, Infrastructure, Critical Success Factors.



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A. BACKGROUND

Building Information Modelling (BIM) has emerged as a transformative paradigm in the construction industry, revolutionizing traditional practices through an integrated digital approach. As a comprehensive digital representation of a building's physical and functional characteristics, BIM enables virtual prototyping that improves coordination, optimizes decision-making, and effectively manages projects throughout the construction lifecycle (National BIM Standard, n.d.). More than just a three-dimensional visualization tool, BIM is a collaborative framework that facilitates the integration of information across disciplines, creating added value through increased efficiency, reduced costs, and enhanced quality of construction output.

The development of BIM has accelerated significantly since the beginning of the 21st century, driven by industry demand for digital solutions capable of addressing the complexities of modern construction projects. Bradley et al. (2016) noted that BIM adoption has increased exponentially across various countries, with implementations proven to increase productivity by up to 20-30% in some case studies. This digital transformation is not limited to the building sector but has expanded to civil infrastructure, plant construction, and other construction industries, marking a fundamental shift towards Construction 4.0 practices.

The significance of BIM in improving project outcomes has been extensively documented in academic literature. (Papadonikolaki et al. 2019) emphasizes the importance of boundary management and effective collaboration within the BIM ecosystem, as well as the need for a strategic approach to organizational management. Kong et al. (n.d.), in a comprehensive study on BIM effectiveness in Malaysia, identified critical factors influencing successful implementation, including top management support, technical competence, and clarity of organizational objectives. Meanwhile, (Rezaei et al. 2019) demonstrated how integrating BIM with life cycle assessment can significantly support the achievement of sustainable building design and meet green building criteria.

Despite its globally recognized benefits, BIM implementation across various segments of the construction industry faces complex, multidimensional challenges. In structural engineering firms, key challenges include resistance to cultural change, technical competency gaps, organizational unpreparedness, and limited regulatory support. In the context of infrastructure projects, (Bradley et al. 2016) identified specific barriers as the lack of universal data standards, the complexity of data integration, and the incompatibility of BIM processes with conventional business processes. Meanwhile, in the prefabricated construction domain, obstacles arise from complex interactions between stakeholders, requiring a collaborative approach and comprehensive network analysis (Xu et al., 2022).

In the increasingly complex BIM ecosystem, the role of the BIM Manager has evolved into a crucial strategic position. Various empirical studies and industry practices demonstrate that the presence of a competent BIM Manager creates an efficient work ecosystem through integrated data management, effective interdisciplinary coordination, and ensuring the interoperability of various software platforms. However, the effectiveness of this role is highly dependent on supporting factors such as clear international standards, solid team collaboration, and a structured information governance framework.

Based on the identified research gaps, this study aims to develop a comprehensive and contextual BIM implementation framework, focusing on four key domains: (1) developing a framework specifically for structural engineering firms using a readiness assessment and gap analysis approach; (2) optimizing the role and competencies of BIM Managers in multidisciplinary project environments; (3) formulating a strategy for implementing BIM in infrastructure projects, with an emphasis on data governance aspects; and (4) a

systematic approach to addressing implementation barriers in prefabricated construction through stakeholder network analysis. The goal of the research is to facilitate a smooth and structured transition towards digital transformation in the national construction ecosystem.

B. IMPLEMENTATION METHODS

This research adopted a multi-strategy methodological approach integrating a systematic literature review, qualitative and quantitative analysis, and empirical validation through a case study. The research stages were comprehensively designed to address the stated research objectives. First, a systematic literature review was conducted of 259 selected documents from an initial 1,080 entries identified through leading academic databases, including Scopus, Science Direct, Web of Science, and Engineering Village. The document selection process was based on criteria of relevance, publication type, and level of significance to the research topic (Bradley et al., 2016). Content analysis was conducted on publication trends, study focus, geographic distribution, project phases, and business process domains to identify global BIM development patterns.

The second stage involved empirical data collection through various methods. For the context of structural engineering firms, a readiness assessment framework was applied that evaluated organizational structure, technical resources, and staff competencies. Critical Success Factors (CSFs) were identified through literature analysis and expert validation, prioritizing key factors such as management support, technical expertise, clarity of objectives, and stakeholder engagement (Papadonikolaki et al., 2019). Analysis of barriers to BIM implementation was conducted through focus group interviews with 13 experts representing various key stakeholders, complemented by social network analysis to map the interconnectedness and transmission pathways of influence between barriers.

The framework was validated through case studies of three different construction projects representing varying BIM implementation contexts. Data were collected from project documents, semi-structured interviews, and observations of BIM software implementations including Revit, Robot Structural Analysis, and Navisworks. Data analysis employed a descriptive-interpretive approach with an emphasis on a socio-technical approach that integrates technological aspects with organizational change management. Network analysis methods were applied to identify key barriers and formulate effective intervention strategies in the context of prefabricated construction (Xu et al., 2022), ensuring that the resulting implementation framework has high practical validity and applicability.

C. RESULT AND DISCUSSION

Based on a comprehensive analysis of various case studies and a literature review, this study identified an effective BIM implementation framework consisting of six key components. These components include: (1) Evaluation of the firm's technological and organizational readiness; (2) Reformulation of BIM objectives aligned with business strategy; (3) Analysis of resource requirements, including software, hardware, and human resource competencies; (4) Analysis of the gap between existing capabilities and project demands; (5) Technical planning, including workflows, responsibilities, and collaboration protocols; and (6) Continuous monitoring and evaluation mechanisms. These findings align with research by Papadonikolaki et al. (2019), which emphasizes the importance of a holistic approach to BIM implementation, where technical and organizational aspects must be synergistically integrated.

The role of the BIM Manager has proven to be a critical factor in the success of BIM implementation. The case study revealed that the BIM Manager not only plays a role in BIM strategy development and data quality control but also serves as a catalyst for interdisciplinary collaboration. Key responsibilities include multidisciplinary data management and validation, ensuring interoperability of software interfaces (such as between Revit and Robot Structural Analysis), coordinating periodic reviews, and conducting clash detection and construction simulations. However, the implementation of this role faces significant challenges, including a lack of consistent procedural standards, a BIM competency gap among professionals, and organizational cultural resistance to digital transformation. These findings align with research by Sampaio (2024), which identified that the effectiveness of a BIM Manager is highly dependent on organizational support and the maturity of the BIM ecosystem.

Further analysis revealed that barriers to BIM implementation are systemic and interconnected. Key barriers include a lack of collaboration among stakeholders, the absence of adequate standards, and industry resistance to technological change. Network analysis indicates that these barriers form a complex pattern of interdependencies, where the lack of standards and collaboration significantly influences other barriers such as economic uncertainty and organizational resistance. To address these challenges, the study proposes an innovative data governance-based strategy that leverages graph and linked data technologies to enhance interoperability and flexibility in data management. This approach enables more dynamic and distributed data management, while supporting process automation and advanced analytics in infrastructure projects, as proposed by (Bradley et al. 2016).

Overall, the research findings confirm that successful BIM implementation requires an integrated approach that emphasizes multi-stakeholder collaboration, improved regulations and standards, and strengthened roles of government and academic institutions. A comprehensive policy framework and support from cutting-edge technology are essential prerequisites for creating a

sustainable and inclusive BIM ecosystem, particularly in the context of prefabricated construction and large-scale infrastructure projects.

D. CONCLUSION AND RECOMMENDATIONS

Based on a synthesis of four studies, this research concludes that effective BIM implementation requires a comprehensive approach that integrates technical, organizational, and regulatory aspects. The proposed implementation framework, which includes readiness evaluation, goal reformulation, needs analysis, gap identification, technical planning, and ongoing monitoring, has been shown to increase BIM adoption in structural engineering firms. The findings confirm that tailoring implementation strategies to the firm's specific context, supported by strong leadership and strategic planning, is a key determinant of successful digital transformation.

The research also confirms the central role of the BIM Manager as a catalyst in a multidisciplinary BIM ecosystem. Competence in data management, technological mastery, and cross-disciplinary coordination capabilities are key factors mediating project success. Furthermore, implementation challenges in infrastructure and prefabricated construction projects, such as the lack of universal data standards, cultural resistance, and fragmented collaboration, can be addressed through the development of an innovative data governance framework, the use of graph-based and linked data technologies, and a network analysis approach to understand the interactions between barriers.

For future research, it is recommended to test the applicability of this framework in real-world case studies and develop more specific BIM readiness assessment tools tailored to the characteristics of each industry segment. Collaboration between the government, academia, and industry in developing standards, regulations, and programs to improve human resource competency is also a strategic step to accelerate the formation of a mature, inclusive, and sustainable BIM ecosystem in Indonesia.

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