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Implementation of Building Information Modelling (BIM) for Design Coordination Efficiency in Small-Scale Construction Projects: A Case-Based Analysis

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Article Information

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Building Information Modeling; design coordination; small-scale construction; clash detection; digital construction

Abstract

The increasing complexity of design coordination in construction projects has encouraged the adoption of digital technologies to improve communication and workflow efficiency. One of the most widely implemented technologies is Building Information Modeling (BIM), which enables integrated project coordination through three-dimensional digital models. This study aimed to analyze the implementation of BIM in improving design coordination efficiency within small-scale construction projects using a case-based analysis approach. The research employed qualitative methods through project observation, document analysis, and semi-structured interviews with project stakeholders. The findings indicate that BIM improved coordination efficiency by supporting centralized information management, faster revision processes, and earlier detection of design clashes between building components. BIM also enhanced communication among stakeholders through integrated visualization and collaborative workflows. However, several challenges related to technical adaptation and stakeholder readiness were still identified during implementation. This study contributes practical insights into the effectiveness of BIM adoption in small-scale construction environments and supports the broader application of digital coordination approaches within the construction industry.

Kata Kunci:
Building Information Modeling; koordinasi desain; konstruksi skala kecil; clash detection; konstruksi digital

Abstrak

Meningkatnya kompleksitas koordinasi desain dalam proyek konstruksi mendorong penerapan teknologi digital untuk meningkatkan efisiensi komunikasi dan alur kerja proyek. Salah satu teknologi yang banyak diterapkan adalah Building Information Modeling (BIM) yang memungkinkan koordinasi proyek secara terintegrasi melalui model digital tiga dimensi. Penelitian ini bertujuan untuk menganalisis implementasi BIM dalam meningkatkan efisiensi koordinasi desain pada proyek konstruksi skala kecil menggunakan pendekatan studi kasus. Penelitian dilakukan menggunakan metode kualitatif melalui observasi proyek, analisis dokumen, dan wawancara semi-terstruktur dengan para pemangku kepentingan proyek. Hasil penelitian menunjukkan bahwa BIM mampu meningkatkan efisiensi koordinasi melalui pengelolaan informasi yang lebih terpusat, proses revisi yang lebih cepat, serta deteksi dini terhadap konflik desain antar komponen bangunan. BIM juga meningkatkan komunikasi antar pihak melalui visualisasi terintegrasi dan alur kerja kolaboratif. Penelitian ini memberikan kontribusi praktis terkait efektivitas penerapan BIM pada lingkungan konstruksi skala kecil.

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I. INTRODUCTION

The construction industry has experienced significant technological transformation in recent years, particularly through the adoption of digital approaches to improve project efficiency and coordination. One of the most widely discussed technologies in this context is Building Information Modeling (BIM), which enables integrated management of design, construction, and operational information within a digital environment. BIM has been recognized as an effective tool for improving communication among project stakeholders, reducing design inconsistencies, and minimizing construction errors during project implementation [1], [2]. As construction projects become increasingly complex, the need for more efficient coordination methods has become critical, including in small-scale projects that often operate with limited resources and simplified management systems.

In practice, design coordination problems remain among the major causes of delays, rework, and cost inefficiencies in construction projects [3], [4], [5]. Conventional coordination methods that rely on two-dimensional drawings and manual communication often lead to discrepancies among architectural, structural, and mechanical designs [6], [7]. These issues are particularly common in small-scale projects, where the adoption of digital technologies is still relatively limited compared to large-scale commercial developments. As a result, many small contractors and design teams continue to face challenges in effectively managing design revisions, information exchange, and interdisciplinary coordination.

Several previous studies have examined the implementation of BIM in improving construction project performance. Research has shown that BIM can support clash detection, visualization, quantity estimation, and collaborative decision-making processes more effectively than traditional methods [8], [9]. Other studies have also reported that BIM implementation helps reduce project errors and improve communication efficiency among stakeholders [10], [11]. However, most existing studies primarily focus on large-scale projects or infrastructure developments with high technological readiness and substantial financial support [7], [12]. Consequently, limited attention has been paid to the implementation of BIM in small-scale construction projects, particularly with respect to practical coordination efficiency.

This condition indicates a research gap regarding how BIM can be effectively implemented in smaller construction environments with operational characteristics different from those of large projects. Small-scale projects generally involve fewer personnel, tighter budgets, and lower levels of technological integration, which may influence the effectiveness of BIM adoption [13], [14]. In addition, many studies emphasize technical BIM capabilities without sufficiently examining its practical impact on day-to-day design coordination activities [1], [13], [15], [16], [17].

Therefore, further investigation is required to understand how BIM contributes to coordination efficiency within real small-scale project settings.

Based on these considerations, this study aims to analyse the implementation of Building Information Modelling (BIM) to improve design coordination efficiency in small-scale construction projects through a case-based approach. The novelty of this research lies in its focus on practical BIM implementation in small-scale construction environments, which have remained underexplored in previous studies. This study is expected to provide practical insights into the role of BIM in reducing coordination problems, improving workflow efficiency, and supporting collaborative project management in small-scale construction practices.

II. RELATED WORK

Building Information Modelling (BIM) has become one of the most influential digital technologies in the construction industry due to its ability to integrate project information into a collaborative, centralised platform. BIM enables stakeholders to visualize building components, manage project data, and improve communication throughout the project lifecycle [18], [19]. Unlike conventional two-dimensional drafting methods, BIM provides three-dimensional digital representations that enable more accurate planning and coordination. This capability has contributed to the increasing adoption of BIM in various construction sectors, including architectural design, structural engineering, and project management.

Previous studies have highlighted the advantages of BIM in improving project coordination and reducing construction conflicts [20], [21], [22]. One of the most widely recognised BIM applications is clash detection, in which conflicts among architectural, structural, and mechanical systems can be identified before construction begins [23], [24]. This capability significantly reduces the likelihood of rework and project delays caused by design inconsistencies. In addition, BIM supports collaborative workflows by enabling multiple stakeholders to access and update project information within a shared digital environment. As a result, communication efficiency and decision-making processes can be improved during project execution.

Several researchers have also examined the relationship between BIM implementation and project efficiency. Studies have shown that BIM reduces design revision time, improves scheduling accuracy, and enhances resource management [25], [26]. Furthermore, BIM-assisted visualisation enables project teams to better understand spatial relationships and construction sequences, thereby minimising misinterpretation of design documents [27], [28], [29]. These advantages have encouraged the broader adoption of BIM in large-scale commercial and infrastructure projects, where project complexity demands intensive coordination among multidisciplinary teams.

Despite these benefits, BIM adoption in small-scale construction projects remains relatively limited. Previous studies suggest that smaller projects often face challenges related to financial constraints, lack of technical expertise, and limited access to digital infrastructure [30], [31]. In many cases, small continue to rely on conventional coordination methods because BIM implementation is perceived as costly and technically demanding [10], [13]. Additionally, the absence of dedicated BIM specialists in smaller organizations may hinder effective technology integration during project execution.

Recent research has attempted to address these issues by exploring simplified BIM implementation strategies suitable for smaller construction environments. Some studies have reported that even partial adoption of BIM can improve communication and reduce coordination errors in small projects [16], [17]. Other research has emphasised that the effectiveness of BIM in small-scale projects depends heavily on stakeholder readiness, software accessibility, and organisational adaptation [32]. However, most existing studies still focus on technical implementation aspects rather than on evaluating BIM's practical impact on the efficiency of daily coordination in real project settings.

Another limitation in the previous literature is the lack of case-based analysis specifically focusing on small-scale construction projects. Many studies evaluate BIM performance through simulations or theoretical frameworks without adequately examining its practical implementation in real-world project conditions [31], [32]. Consequently, there is still limited understanding of how BIM influences coordination workflows, communication patterns, and revision management in small construction teams. This gap indicates the need for more contextual and practice-oriented studies that reflect real operational conditions.

Therefore, this study examines the implementation of BIM in small-scale construction projects using a case-based analysis. Unlike prior studies that primarily emphasise technological capabilities, this research evaluates BIM from the perspective of practical coordination efficiency. Through this approach, the study aims to contribute a more contextual understanding of BIM implementation challenges and benefits within smaller construction environments.

III. METHOD

This study employed a qualitative, case-based analysis to examine the implementation of Building Information Modelling (BIM) to improve design coordination efficiency in small-scale construction projects. The qualitative approach was selected because the study focused on understanding coordination processes, communication patterns, and workflow changes occurring during BIM implementation in real project environments. The research was conducted through direct observation and analysis of project coordination activities involving design and construction teams. This approach enabled a more contextual understanding of BIM utilization under practical operational conditions.

The case study was conducted on a small-scale construction project involving architectural and structural coordination during the design and pre-construction stages. The selected project exhibited typical characteristics of small-scale construction practices, including limited project personnel, a relatively short project duration, and a simplified organisational structure. BIM was implemented primarily for three-dimensional visualisation, design coordination, and clash detection among building components. The study focused on how BIM supported coordination activities compared to conventional two-dimensional drawing-based methods.

Data collection was carried out through several techniques, including project observation, document analysis, and semi-structured interviews with project stakeholders. Observations were conducted to identify coordination workflows, revision processes, and communication patterns during project execution. Project documents, such as design drawings, coordination reports, and revision records, were also analysed to support the evaluation process. In addition, interviews were conducted with architects, engineers, and project coordinators to obtain practical insights regarding the perceived benefits and challenges of BIM implementation in the project environment.

To ensure systematic analysis, the collected data were categorised into several aspects of coordination efficiency. These aspects included the frequency of design revisions, communication effectiveness, clash-detection capability, coordination time, and information accessibility among project stakeholders. The analysis focused on comparing coordination conditions before and after BIM implementation, based on observations and stakeholder experiences collected during the study. This comparative approach allowed the study to identify operational improvements associated with BIM adoption.

The BIM implementation process in this study utilized commercially available BIM software commonly adopted in architectural and construction practices. The software was used to develop integrated three-dimensional models that combined architectural and structural elements into a unified digital environment. Through this model, potential design conflicts and inconsistencies could be identified earlier before construction activities commenced. The visualization capability of BIM also facilitated clearer communication among project participants during coordination meetings and revision discussions.

Data analysis was conducted using descriptive qualitative methods to interpret findings from observations, interviews, and project documentation. The analysis emphasized identifying recurring coordination issues, workflow improvements, and practical impacts associated with

BIM implementation. To strengthen the validity of the findings, data triangulation was performed by comparing information obtained from different sources and stakeholders. Through this methodology, the study aimed to provide a practical, contextual evaluation of BIM implementation to improve coordination efficiency in small-scale construction projects.

IV. RESULT AND DISCUSSION

The implementation of Building Information Modelling (BIM) in the observed small-scale construction project demonstrated noticeable improvements in the efficiency of design coordination compared to the previously used conventional workflow. Before BIM adoption, project coordination relied primarily on two-dimensional drawings and manual communication among project participants. This condition frequently resulted in inconsistencies between architectural and structural drawings, delayed revisions, and repeated clarifications during coordination meetings. After BIM implementation, the coordination process became more integrated due to the availability of a centralised digital model accessible to the project team.

One of the most significant findings of this study was the reduction in design conflicts identified during the coordination stage. Through the BIM-based three-dimensional model, several clashes between structural and architectural components were detected before entering the construction phase. This early detection capability minimized the need for repeated revisions and reduced the risk of construction errors in the field. In addition, stakeholders reported that visual representation through BIM improved their understanding of spatial relationships and building components, making coordination discussions more efficient and easier to interpret. These findings indicate that BIM provides practical advantages not only sfor technical visualization but also for enhancing communication effectiveness among project participants.

The implementation of BIM also improved coordination time and workflow management. Based on project observations and stakeholder interviews, the duration of design coordination meetings decreased because project teams could directly identify problematic areas within the integrated model. Under the previous conventional approach, coordination discussions often required manual comparison across multiple drawings, increasing the likelihood of misinterpretation and prolonging revision cycles. BIM reduced this inefficiency by enabling real-time visualisation and centralised access to information during the coordination process. As a result, project participants experienced a more streamlined workflow during design review activities. Table 1 presents a comparative overview of coordination conditions before and after BIM implementation within the studied project environment.

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Table 1. Comparison of Coordination Conditions Before and After BIM Implementation

Evaluation Aspect	Conventional Method	BIM-based Coordination
Design visualization	2D drawings	Integrated 3D model
Clash Detection	Manual identification	Automated visual detection
Revision Process	Repetitive and time-consuming	Faster and more centralized
Communication flow	Fragmented among teams	More collaborative
Coordination efficiency	Moderate	Improved

The findings shown in Table 1 indicate that BIM implementation positively influenced several operational aspects of project coordination. The most notable improvement was observed in communication and revision management, where the integrated model enabled stakeholders to work within a shared visual environment. This finding supports previous studies that emphasized BIM's capability in improving interdisciplinary coordination and reducing design inconsistency [12], [30], [33], [34]]. However, unlike many previous studies focusing on large-scale projects, this research demonstrates that similar benefits can also be achieved in smaller construction environments with relatively limited resources.

Despite the observed improvements, several implementation challenges were identified during the study. One of the primary issues involved the limited technical experience of some project personnel in operating BIM software. In the early stages of implementation, additional time was required for model adjustments and adaptation to the new digital workflow. In addition, hardware limitations and software licensing costs were perceived as barriers for broader BIM adoption in small-scale projects. These findings are consistent with earlier research highlighting that technological readiness and resource availability remain major obstacles for BIM implementation in smaller construction organizations [33], [34].

Figure 1 illustrates the BIM-based coordination workflow implemented in the studied small-scale construction project, beginning from the preparation of conventional design documents to the final design revision stage. The workflow demonstrates how BIM serves not only as a visualisation tool but also as an integrated coordination platform that facilitates communication among project stakeholders throughout the design process. Through the centralized digital model, architectural and structural elements could be reviewed simultaneously, enabling earlier identification of design inconsistencies and reducing dependency on repetitive manual checking procedures. This finding indicates that BIM supports a more systematic and collaborative coordination mechanism than conventional drawing-based approaches, particularly in projects with limited personnel and simplified organisational structures. In addition, the workflow highlights the practical role of clash detection in minimizing revision cycles and supporting faster decision-making during coordination meetings. The implementation observed in this study further suggests that even partial BIM adoption can improve workflow transparency and information accessibility in small-scale construction environments, despite existing limitations in technical expertise and technological adaptation.

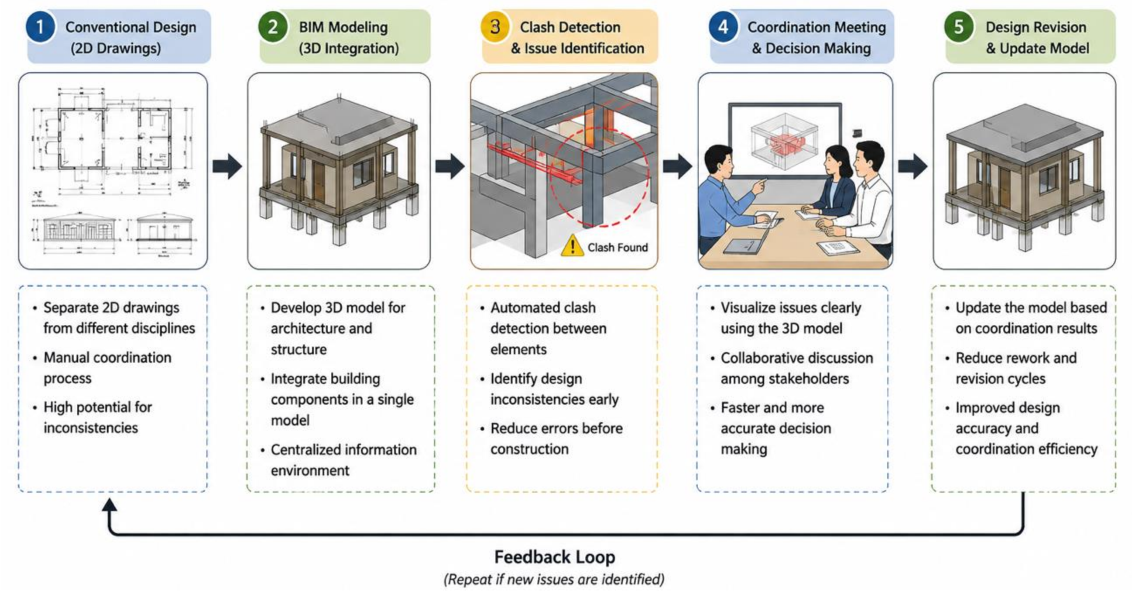

Figure 1. BIM-based Design Coordination Workflow (Small-scale construction project)

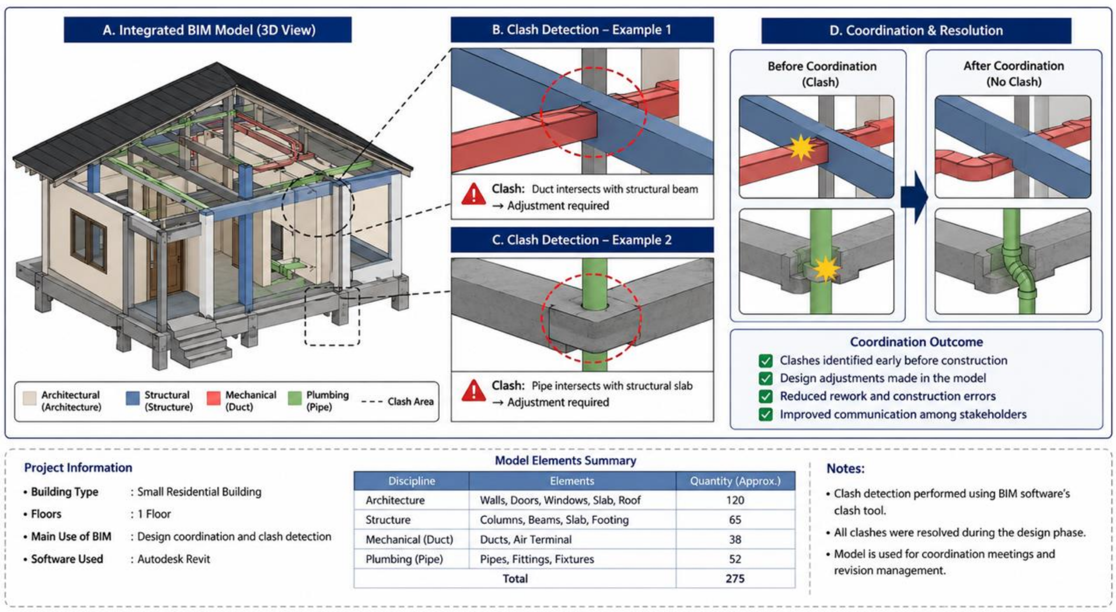

Figure 2. Scenario Sample of Integrated BIM Model and Clash Detection.

Figure 2 presents an example of the integrated BIM model used during the coordination process in the studied small-scale construction project. The visualisation demonstrates how architectural, structural, and utility components were integrated into a unified digital environment, enabling potential clashes and design inconsistencies to be identified before construction commenced. Several coordination issues, particularly at intersections between structural and utility elements,

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were identified directly in the BIM model and subsequently resolved during the design revision stage. This finding indicates that BIM significantly improves coordination transparency and enables project stakeholders to evaluate design conflicts more efficiently compared to conventional two-dimensional drawing methods. The ability to visualize conflicts spatially also reduced ambiguity during coordination meetings and accelerated decision-making among project participants.

These results are consistent with previous studies reporting that BIM-based clash detection reduces rework, improves interdisciplinary coordination, and minimises construction errors during project execution [12], [13], [35]. However, unlike many prior studies that primarily focus on large-scale infrastructure or commercial projects, the present study demonstrates that BIM integration can also provide measurable coordination benefits in smaller construction environments with limited organizational complexity. The findings further suggest that the effectiveness of BIM implementation in small-scale projects is strongly associated with visualisation capabilities and centralised information management, rather than with the full adoption of advanced BIM functionalities. Nevertheless, the study also observed that the success of BIM coordination depends on stakeholder adaptability and technical familiarity with digital workflows, which remains a common challenge in smaller construction organizations. Overall, the implementation shown in Figure 2 supports the argument that selective and practical BIM adoption can improve coordination efficiency even in projects with constrained resources and simplified management structures.

Another important finding relates to stakeholder adaptation during the coordination process. While BIM improved communication efficiency, the transition from conventional methods to digital collaboration required organizational adjustments among project participants. Some stakeholders initially relied heavily on printed drawings and experienced difficulty adapting to model-based coordination practices. However, over time, the project team reported greater familiarity with the BIM workflow, particularly itbecause to simplified revision tracking and information sharing. This indicates that the effectiveness of BIM implementation is influenced not only by the availability of technology but also by user readiness and organisational acceptance.

The results of this study further confirm that BIM implementation can provide practical benefits even in projects with relatively simple organizational structures. Previous literature often associates BIM adoption with large-scale construction projects involving complex multidisciplinary coordination [7], [17]. In contrast, this study demonstrates that small-scale projects can also achieve measurable improvements in coordination through selective BIM implementation focused on visualisation and design integration. This finding provides further practical insight into the scalability of BIM adoption across project categories.

Nevertheless, several limitations of this study should be acknowledged. The research was conducted within a single project environment, which may limit the generalizability of the findings across broader construction contexts. In addition, the evaluation focused primarily on coordination efficiency rather than on long-term economic impacts, such as cost reductions or productivity measures. Future studies are recommended to involve multiple project cases and incorporate quantitative performance indicators to provide a more comprehensive evaluation of BIM effectiveness in small-scale construction projects. Further investigation into organisational readiness and technology adoption strategies is also necessary to support broader BIM implementation in developing construction environments.

V. CONCLUSION AND RECOMMENDATIONS

This study demonstrates that implementing Building Information Modelling (BIM) can significantly improve the efficiency of design coordination in small-scale construction projects. The findings indicate that BIM facilitates better communication among stakeholders through integrated three-dimensional visualization and centralized information management. The use of BIM also contributed to earlier identification of design clashes, reduction of repetitive revision processes, and improved coordination workflow during project execution. Compared with conventional drawing-based coordination methods, BIM provided a more systematic and collaborative environment that supported faster, more accurate decision-making.

The results further reveal that BIM implementation is not limited to large-scale projects with complex organizational structures. Even in small-scale construction environments, BIM provided practical operational benefits, particularly in design integration and coordination transparency. However, the effectiveness of BIM adoption remains influenced by several factors, including stakeholder readiness, technical capability, and access to adequate digital infrastructure. Initial adaptation challenges observed during implementation indicate that organisational and human resource aspects remain important considerations for successful BIM integration.

Despite the positive outcomes identified in this study, several limitations should be acknowledged. The research was conducted within a single project case and focused primarily on coordination efficiency rather than on broader project performance indicators, such as cost optimisation or productivity. Therefore, future studies are recommended to involve multiple case studies and incorporate quantitative evaluation methods to provide more comprehensive findings regarding BIM effectiveness in small-scale construction projects. Further research is also encouraged to explore BIM adoption strategies, stakeholder readiness assessment, and the integration of BIM with other digital construction technologies to support wider implementation in developing construction industries.

Conflict of Interest

The authors declare no conflicts of interest that could have influenced the research process, data analysis, or the publication of this article.

Data Availability

The data used in this study are available from the corresponding author upon reasonable request.

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