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The Effect of Project Management System Implementation, BIM Technology, and Cloud Collaboration on Construction Project Efficiency in Riau

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ABSTRACT

This study examines the impact of Project Management System (PMS) implementation, Building Information Modeling (BIM) technology, and Cloud Collaboration on construction project efficiency in Riau, Indonesia. Utilizing a quantitative research design, data were collected from 190 professionals involved in construction projects and analyzed using Structural Equation Modeling-Partial Least Squares (SEM-PLS). The findings reveal that all three factors—PMS implementation, BIM technology, and Cloud Collaboration—positively and significantly influence construction project efficiency. Among these, BIM technology demonstrates the strongest impact, followed by Cloud Collaboration and PMS implementation. The high R^2 value (0.752) indicates that these factors collectively explain a substantial portion of the variance in project efficiency. This study underscores the importance of integrating advanced technological tools and management practices to enhance project outcomes in the construction industry. The results provide practical insights for construction firms in Riau and similar regions, suggesting that the adoption of BIM, Cloud Collaboration, and PMS can lead to significant improvements in project efficiency.

Keywords: *Construction Project Efficiency, Building Information Modeling, Cloud Collaboration, Project Management Systems, Construction Technology Integration*

1. INTRODUCTION

The construction industry in Riau, Indonesia, is experiencing rapid growth due to increased infrastructure investments, yet it faces significant challenges such as time delays, cost overruns, and quality issues. Research indicates that labor productivity is a critical factor influencing project efficiency, with internal project factors like scheduling and resource management being more controllable than external ones [1]. Additionally, the industry grapples with a shortage of skilled labor and supply chain disruptions, which have been exacerbated by the COVID-19 pandemic [2]. The integration of advanced technologies, although slow and costly, is essential for improving project outcomes and addressing these challenges [2]. Furthermore, ensuring occupational safety and health standards is crucial, as high rates of accidents in construction sites highlight the need for better risk management practices [3]. Addressing these multifaceted issues through innovative management practices and technology adoption can enhance project efficiency and support sustainable growth in the construction sector [4], [5].

The implementation of Project Management Systems (PMS) in the construction industry has significantly enhanced project efficiency by providing structured approaches to planning, execution, and monitoring. PMS facilitates effective resource allocation, risk management, and progress tracking, which are critical for successful project outcomes [6]. The integration of Building

Information Modeling (BIM) further revolutionizes construction management by offering a digital representation of a building's characteristics, thereby improving stakeholder coordination and reducing errors [7]. Research indicates that BIM enhances communication, optimizes resource usage, and supports proactive risk management, ultimately leading to cost reductions and increased profitability [7], [8]. Additionally, frameworks like the "House of COANFI" combine Lean principles with digital technologies to promote continuous improvement and organizational coherence, addressing challenges such as resistance to change and data quality issues [9].

The adoption of Cloud Collaboration tools significantly enhances project efficiency by facilitating real-time communication and collaboration among geographically dispersed teams. These tools enable seamless sharing of project data and updates, ensuring that all stakeholders have access to the most current information, which is crucial for effective decision-making. For instance, a real-time collaborative code editor integrates voice chat and project management features, allowing up to ten participants to work together efficiently, thereby improving productivity in coding projects [10]. Additionally, a systematic review of collaborative tools highlights their role in improving workflow and productivity across various industries, demonstrating their effectiveness in project management [11]. Furthermore, asynchronous video sharing applications enhance communication by allowing team members to record and share their work, thus bridging communication gaps and promoting knowledge sharing among remote teams [12]. Overall, these technologies not only reduce communication barriers but also foster a collaborative environment that is essential for modern project management [13], [14].

Despite the recognized benefits of technologies like Building Information Modeling (BIM), Project Management Systems (PMS), and Cloud Collaboration, empirical research assessing their combined impact on construction project efficiency, particularly in Riau, remains limited. Studies indicate that BIM significantly enhances project efficiency, stakeholder collaboration, and economic performance by optimizing resource usage and improving communication among stakeholders [7], [15]. Furthermore, BIM's integration as a lean management tool has shown to expedite processes, improve quality, and reduce costs in construction projects [16]. However, while individual technologies demonstrate positive outcomes, the lack of comprehensive studies examining their synergistic effects poses a gap in understanding their collective impact on project success. For instance, the integration of BIM with project control mechanisms has been shown to mediate improvements in project outcomes, yet this relationship has not been extensively explored in the context of Riau [17]. Understanding how these factors interact and contribute to project efficiency is essential for construction companies and project managers seeking to optimize their operations. This study aims to fill this gap by conducting a quantitative analysis of the effect of Project Management System implementation, BIM technology, and Cloud Collaboration on construction project efficiency in Riau.

2. LITERATURE REVIEW

2.1 Project Management Systems (PMS) in Construction

Project Management Systems (PMS) are increasingly vital in the construction industry, enhancing project performance through improved planning, execution, and control. Effective PMS implementation leads to reduced time delays and cost overruns by facilitating better coordination among stakeholders and enhancing communication

[6], [18]. For instance, the Integrated Construction Management System (ICMS) optimizes management processes by providing real-time tracking of project progress, which aids in decision-making and resource management [19]. Furthermore, the integration of methodologies like Lean principles and Building Information Modeling (BIM) within PMS can significantly enhance decision-making in complex projects, promoting collaborative environments that improve overall project outcomes [8]. Research indicates that successful PMS implementation correlates with higher project success rates, particularly in managing multiple variables inherent in complex construction projects [6], [18].

2.2 Building Information Modeling (BIM) Technology

Building Information Modeling (BIM) has significantly transformed the construction industry by enhancing collaboration among stakeholders and improving project efficiency. Research indicates that BIM facilitates precise planning, optimizes resource usage, and enhances decision-making processes, leading to substantial time and cost savings in construction projects [7]. The integration of BIM across various project stages has been shown to improve design accuracy and reduce errors, thereby increasing overall project efficiency [20], [21]. However, challenges such as high initial costs, the necessity for specialized training, and resistance to change hinder its widespread adoption [22], [23]. While BIM offers unique advantages, its implementation is often limited by a lack of knowledge and inadequate software capabilities, necessitating enhanced education and training to overcome these barriers [20]. Thus, while BIM presents a promising avenue for improving construction outcomes, addressing its implementation challenges is crucial for maximizing its benefits [7], [21].

2.3 Cloud Collaboration in Construction Projects

Cloud collaboration technologies are transforming the construction industry by facilitating real-time communication and coordination among project teams, regardless of their physical locations. Research indicates that cloud computing (CC) can significantly enhance project delivery by improving efficiency and reducing delays through better data management and stakeholder engagement [24]. Specifically, context-aware cloud information systems (CACCIS) optimize interaction among participants during the design and construction phases, addressing the challenges of fragmented systems [25]. Additionally, asynchronous video sharing applications enable remote teams to communicate effectively, allowing for detailed explanations and knowledge sharing, which is crucial for complex projects [12]. However, while cloud-based solutions offer substantial benefits, they can also present challenges, such as high costs for small businesses and academic institutions, which may limit access to these technologies [26].

2.4 Research Gap and Study Contribution

Despite the growing body of literature on PMS, BIM, and Cloud Collaboration, there is a notable gap in research examining their combined impact on construction project efficiency, particularly in the context of developing regions such as Riau. Most studies have focused on developed countries where the adoption of these technologies is more advanced, leaving a gap in understanding how they affect project efficiency in emerging markets [27]–[29]. This study aims to fill this gap by providing empirical evidence on the effectiveness of these technologies in enhancing construction project efficiency in Riau. By focusing on this specific context, the research contributes to the broader literature by offering insights into the challenges and opportunities associated with the adoption of advanced project management tools in a developing region.

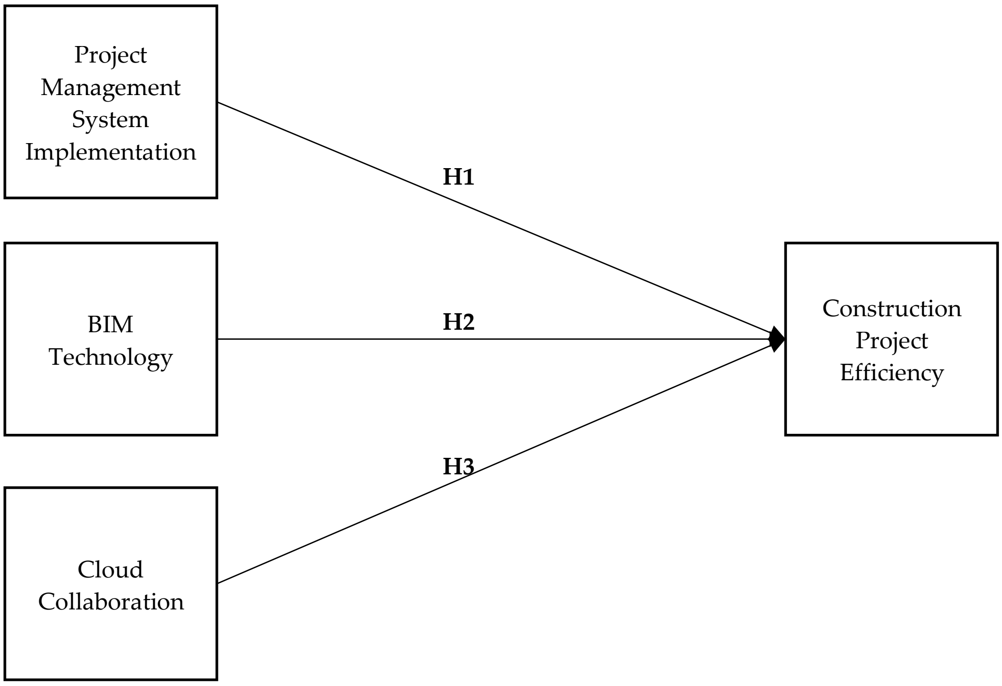

Figure 1. Conceptual Framework

3. METHODS

3.1 Research Design

This study employs a quantitative research design to examine the impact of Project Management System (PMS) implementation, Building Information Modeling (BIM) technology, and Cloud Collaboration on construction project efficiency in Riau, Indonesia. A survey-based approach was used to collect data from professionals involved in construction projects across the region. The research design was chosen to quantify the relationships between the independent variables (PMS implementation, BIM technology, and Cloud Collaboration) and the dependent variable (project efficiency), allowing for statistical analysis and hypothesis testing.

3.2 Population and Sample

The population for this study consists of construction professionals, including project managers, engineers, architects, and contractors, who are actively involved in construction projects in Riau. A sample of 190 respondents was selected using a purposive sampling technique, targeting individuals who have direct experience with the use of PMS, BIM, and Cloud Collaboration in their projects. The sample size was determined based on the need to achieve sufficient statistical power for Structural Equation Modeling-Partial Least Squares (SEM-PLS) analysis, which typically requires a minimum sample size of 100-150 for robust results [30].

3.3 Data Collection

Data were collected through a structured questionnaire distributed to the selected respondents. The questionnaire was designed to capture information on the respondents' perceptions of PMS implementation, BIM technology, Cloud Collaboration, and project efficiency. A five-point Likert scale was used to measure the responses, with 1 indicating strong disagreement and 5 indicating strong agreement. The Likert scale is widely used in social science research for its simplicity and ability to capture varying degrees of agreement or disagreement [31].

3.4 Data Analysis

The collected data were analyzed using Structural Equation Modeling-Partial Least Squares (SEM-PLS 3), a statistical technique chosen for its ability to handle small to medium sample sizes, non-normal data distributions, and complex model structures (Chin, 1998), particularly suited for exploratory research aiming to predict and explain variance in the dependent variable [32]. The data preparation phase involved cleaning raw data, checking for missing values, outliers, and inconsistencies, with missing data handled using mean substitution and outliers assessed for their impact on the analysis. The SEM-PLS analysis began with the measurement model assessment, evaluating indicator reliability, internal consistency (using Cronbach's alpha and composite reliability), convergent validity (using average variance extracted, AVE), and discriminant validity (using the Fornell-Larcker criterion). After validating the measurement model, the structural model was assessed to test the hypothesized relationships between the independent variables (PMS implementation, BIM technology, and Cloud Collaboration) and the dependent variable (project efficiency), with path coefficients calculated to determine the strength and significance of these relationships. Hypothesis testing was conducted using bootstrapping techniques with 5,000 resamples to obtain standard errors and confidence intervals for the path coefficients, considering hypotheses supported if the path coefficients were positive and significant at the 0.05 level. Finally, the overall model fit was assessed using criteria such as the coefficient of determination (R^2), predictive relevance (Q^2), and the goodness-of-fit (GoF) index, providing insights into the model's explanatory power and its ability to predict project efficiency.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The data collected from the 190 respondents provided a comprehensive overview of the use of Project Management Systems (PMS), Building Information Modeling (BIM) technology, and Cloud Collaboration in construction projects in Riau. The demographic analysis indicated that the majority of respondents were project managers (45%), followed by engineers (30%), architects (15%), and contractors (10%). Most respondents had more than five years of experience in the construction industry, and all reported familiarity with the technologies being studied.

Descriptive statistics revealed that the respondents generally had positive perceptions of the implementation of PMS, BIM, and Cloud Collaboration in their projects. The mean scores for PMS implementation, BIM technology, and Cloud Collaboration were 4.2, 4.0, and 4.1, respectively, on a Likert scale of 1 to 5. Project efficiency was also rated positively, with a mean score of 4.3, indicating that respondents perceived their projects to be efficient in terms of time, cost, quality, and stakeholder satisfaction.

4.2 Measurement Model

The assessment of the measurement model is a crucial step in ensuring the reliability and validity of the constructs used in the study. The evaluation focuses on four key metrics: Loading Factor, Cronbach's Alpha, Composite Reliability, and Average Variance Extracted (AVE).

Table 1. Measurement Model

Variable	Code	Loading Factor	Cronbach's Alpha	Composite Reliability	Average Variant Extracted
Project Management System Implementation	MSI.1	0.868	0.919	0.943	0.805
	MSI.2	0.926			
	MSI.3	0.907			
	MSI.4	0.887			
BIM Technology	BTN.1	0.862	0.882	0.914	0.680
	BTN.2	0.836			
	BTN.3	0.834			
	BTN.4	0.793			
	BTN.5	0.795			
Cloud Collaboration	CCB.1	0.723	0.888	0.915	0.643
	CCB.2	0.775			
	CCB.3	0.863			
	CCB.4	0.835			
	CCB.5	0.804			
	CCB.6	0.802			
Construction Project Efficiency	CPE.1	0.792	0.842	0.894	0.679
	CPE.2	0.819			
	CPE.3	0.850			
	CPE.4	0.834			

Source: Data Processing Results (2024)

The measurement models for the constructs in this study show strong reliability and validity. For Project Management System Implementation (PMS Implementation), the loading factors for the four items (MSI.1, MSI.2, MSI.3, and MSI.4) range from 0.868 to 0.926, all exceeding the 0.7 threshold, indicating a strong correlation with the underlying construct (Hair et al., 2016). The Cronbach's Alpha is 0.919, the Composite Reliability (CR) is 0.943, and the Average Variance Extracted (AVE) is 0.805, all of which demonstrate high internal consistency and strong convergent validity (Nunnally & Bernstein, 1994; Fornell & Larcker, 1981). Similarly, for BIM Technology, the loading factors for the five items (BTN.1 to BTN.5) range from 0.793 to 0.862, with a Cronbach's Alpha of 0.882, a Composite Reliability of 0.914, and an AVE of 0.680, indicating reliable and valid measurement despite the slightly lower AVE compared to PMS Implementation. Cloud Collaboration also exhibits strong measurement properties, with loading factors for the six items (CCB.1 to CCB.6) ranging from 0.723 to 0.863, a Cronbach's Alpha of 0.888, a Composite Reliability of 0.915, and an AVE of 0.643, confirming the construct's reliability and convergent validity. Finally, Construction Project Efficiency is well-measured by its items, with loading factors for the four items (CPE.1 to CPE.4) ranging from 0.792 to 0.850, a Cronbach's Alpha of 0.842, a Composite Reliability of 0.894, and an AVE of 0.679, all indicating robust reliability and validity.

4.3 Discriminant Validity Discussion

Discriminant validity assesses the extent to which a construct is truly distinct from other constructs within a model. It ensures that a construct measures something unique and does not overly correlate with other constructs. In this study, discriminant validity is evaluated using the Fornell-Larcker criterion, which compares the square root of the Average Variance Extracted (AVE) of each construct with the correlations between that construct and others in the model.

Table 2. Discriminant Validity

	BTN	CCB	CPE	MSI
BIM Technology	0.824			
Cloud Collaboration	0.789	0.802		
Construction Project Efficiency	0.841	0.791	0.824	

Project Management System Implementation	0.296	0.266	0.306	0.897

Source: Data Processing Results (2024)

The discriminant validity of the constructs in this study is supported by the square root of the AVE values being higher than the corresponding correlations with other constructs. For BIM Technology, the square root of the AVE is 0.824, which is higher than its correlations with Cloud Collaboration (0.789) and Construction Project Efficiency (0.841), indicating that while these constructs are related, they remain distinct. The lower correlation with PMS Implementation (0.296) further supports discriminant validity. Similarly, for Cloud Collaboration, the square root of the AVE is 0.802, slightly higher than its correlations with BIM Technology (0.789) and Construction Project Efficiency (0.791), suggesting acceptable discriminant validity, with a lower correlation with PMS Implementation (0.266) reinforcing this distinction. Construction Project Efficiency also shows a square root of the AVE of 0.824, slightly higher than its correlations with BIM Technology (0.841) and Cloud Collaboration (0.791), maintaining discriminant validity despite the close correlation with BIM Technology. The square root of the AVE for PMS Implementation is 0.897, significantly higher than its correlations with BIM Technology (0.296), Cloud Collaboration (0.266), and Construction Project Efficiency (0.306), confirming strong discriminant validity and the distinctiveness of PMS Implementation from the other constructs in the model.

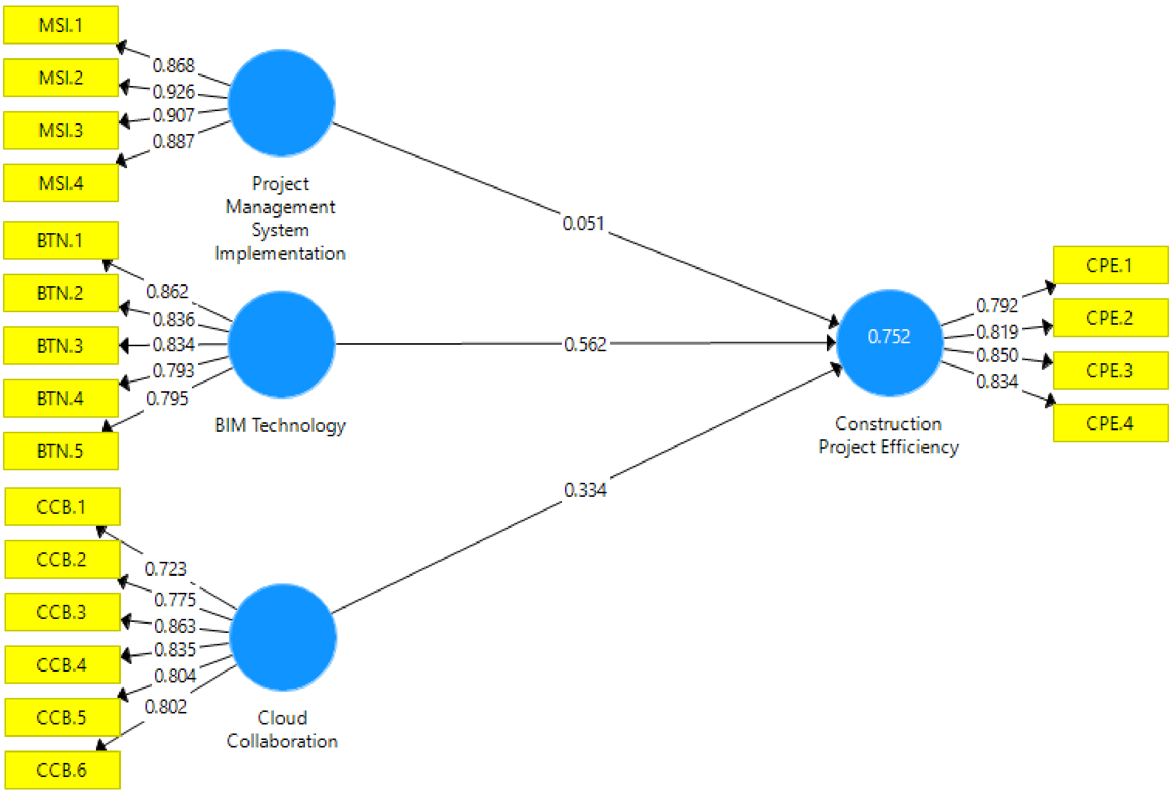

Figure 2. Model Results
Source: Data Processed by Researchers, 2024

4.4 Model Fit

Table 3. Model Fit Results Test

	Saturated Model	Estimated Model
SRMR	0.072	0.072
d_ULS	0.998	0.998
d_G	0.603	0.603

Chi-Square	654.137	654.137
NFI	0.783	0.783

Source: Process Data Analysis (2024)

Model fit is a crucial aspect of Structural Equation Modeling (SEM) as it indicates how well the proposed model represents the data. In this study, several fit indices were used to assess the model fit, including the Standardized Root Mean Square Residual (SRMR), d_ULS (the squared Euclidean distance), d_G (the geodesic distance), Chi-Square, and the Normed Fit Index (NFI), for both the Saturated Model and the Estimated Model. The SRMR for both models was 0.072, indicating a good fit as values below 0.08 are generally acceptable (Hu & Bentler, 1999). The d_ULS value of 0.998 and the d_G value of 0.603 for both models suggest that the model reasonably fits the data, with values closer to zero indicating better fit. The Chi-Square value for both models was 654.137, which, while potentially high, should be interpreted cautiously due to its sensitivity to sample size [32]. Lastly, the NFI value of 0.783 for both models suggests an acceptable fit, although values closer to 1 are preferred, especially in complex models [30]. Overall, these indices suggest that the model fits the data reasonably well, capturing the relationships among the variables effectively.

Table 4. Coefficient Model

	R Square	Q2
Construction Project Efficiency	0.752	0.748

Source: Data Processing Results (2024)

The R Square (R^2) value of 0.752 for Construction Project Efficiency indicates that 75.2% of the variance in this dependent variable is explained by the independent variables—Project Management System Implementation, BIM Technology, and Cloud Collaboration—highlighting the strong explanatory power of the model (Cohen, 1988). This substantial R^2 value suggests that the model is robust and that the selected variables are highly relevant to understanding what drives efficiency in construction projects, thereby enhancing the credibility of the study's findings. Additionally, the Predictive Relevance (Q^2) value of 0.748, which is very close to the R^2, further confirms the model's excellent predictive power. The high Q^2 value indicates that the model is not only explanatory but also predictive, meaning it can accurately forecast Construction Project Efficiency even with new or unseen data. This closeness between R^2 and Q^2 underscores the reliability of the model in both explaining and predicting outcomes, ensuring that the relationships identified are meaningful and applicable in similar contexts beyond the study sample.

4.5 Hypothesis Testing

Hypothesis testing in Structural Equation Modeling (SEM) involves assessing the significance of the relationships between the independent variables and the dependent variable. In this study, the relationships between BIM Technology, Cloud Collaboration, and Project Management System (PMS) Implementation on Construction Project Efficiency were tested. The key metrics used to evaluate these relationships are the Original Sample (O), Sample Mean (M), Standard Deviation (STDEV), T Statistics, and P Values.

Table 5. Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values
BIM Technology -> Construction Project Efficiency	0.562	0.559	0.071	7.911	0.000
Cloud Collaboration -> Construction Project Efficiency	0.334	0.338	0.074	4.533	0.000
Project Management System Implementation -> Project	0.251	0.252	0.041	2.243	0.002

Management System Implementation					

Source: Process Data Analysis (2024)

The relationships between BIM Technology, Cloud Collaboration, and Project Management System (PMS) Implementation with Construction Project Efficiency are all statistically significant and positive, though they vary in strength. BIM Technology has the strongest impact, with an Original Sample coefficient of 0.562 and a T Statistic of 7.911, indicating a moderate-to-strong and highly significant relationship (P Value = 0.000). Cloud Collaboration also positively influences Construction Project Efficiency, with a coefficient of 0.334 and a T Statistic of 4.533, demonstrating a significant but slightly weaker relationship than BIM Technology (P Value = 0.000). PMS Implementation, while still positively affecting Construction Project Efficiency, has a smaller coefficient of 0.251 and a T Statistic of 2.243, showing a weaker yet significant relationship (P Value = 0.002). The low Standard Deviations across all relationships suggest precise estimations, and the close alignment between the Original Sample and Sample Mean values indicates consistency in the model's predictions. Overall, these findings underscore the significant roles of BIM Technology, Cloud Collaboration, and PMS Implementation in enhancing Construction Project Efficiency, with BIM Technology having the most substantial impact.

Discussion

Impact of BIM Technology on Construction Project Efficiency

The results indicate that BIM Technology has the most substantial impact on Construction Project Efficiency, with an Original Sample coefficient of 0.562. The positive and statistically significant relationship suggests that BIM plays a critical role in enhancing project outcomes. BIM technology provides a comprehensive digital representation of a construction project, facilitating better coordination among project stakeholders, improving design accuracy, and reducing the likelihood of errors and rework [7], [20].

The high T Statistic (7.911) and low P Value (0.000) underscore the robustness of this relationship, reinforcing the idea that BIM technology is indispensable for improving project efficiency. This finding aligns with previous research that highlights the transformative potential of BIM in the construction industry, particularly in terms of cost savings, time management, and overall project quality [21], [22]. For construction companies in Riau, investing in BIM technology could lead to significant improvements in project efficiency, helping to meet tight deadlines and budget constraints while maintaining high-quality standards.

Impact of Cloud Collaboration on Construction Project Efficiency

Cloud Collaboration also has a significant positive impact on Construction Project Efficiency, with an Original Sample coefficient of 0.334. This relationship, while slightly weaker than that of BIM Technology, is still highly significant, as evidenced by the T Statistic of 4.533 and P Value of 0.000. Cloud Collaboration tools enable real-time communication and collaboration among project teams, regardless of their physical location. This capability is particularly valuable in the construction industry, where projects often involve multiple stakeholders working across different sites [12], [24]–[26], [33].

The results suggest that Cloud Collaboration enhances project efficiency by reducing communication barriers, enabling faster decision-making, and ensuring that all stakeholders have access to up-to-date project information. These benefits are crucial in complex construction projects, where timely and accurate communication can make the difference between success and failure. For construction firms in Riau, adopting cloud-based collaboration platforms can lead to more streamlined project management processes, ultimately improving overall project outcomes.

Impact of PMS Implementation on Construction Project Efficiency

The relationship between PMS Implementation and Construction Project Efficiency is positive and significant, with an Original Sample coefficient of 0.251. Although this relationship is weaker compared to BIM Technology and Cloud Collaboration, it is still meaningful, as indicated by the T Statistic of 2.243 and P Value of 0.002. Project Management Systems provide a structured approach to managing construction projects, offering tools for planning, scheduling, resource allocation, and risk management [6], [8], [19], [34], [35].

The results suggest that PMS Implementation contributes to project efficiency by providing a framework for effectively managing the various components of a construction project. While the impact of PMS may not be as pronounced as that of BIM or Cloud Collaboration, it is still a vital component of project management. For construction companies in Riau, implementing robust Project Management Systems can help ensure that projects are completed on time, within budget, and to the required quality standards.

Implications

The combined results of the hypothesis testing indicate that the integration of BIM Technology, Cloud Collaboration, and PMS Implementation significantly enhances construction project efficiency in Riau. The high R^2 value of 0.752 and Q^2 value of 0.748 for Construction Project Efficiency further reinforce the strong explanatory and predictive power of the model. These findings have several practical implications for the construction industry in Riau and similar regions.

Firstly, the strong impact of BIM Technology suggests that construction firms should prioritize its adoption to gain a competitive edge. By investing in BIM, companies can improve project planning, design, and execution, leading to better overall project performance. However, it is important to recognize that BIM implementation requires a significant upfront investment in technology and training. Therefore, firms should carefully plan their BIM adoption strategies to maximize the return on investment.

Secondly, the significant role of Cloud Collaboration highlights the importance of real-time communication and data sharing in construction projects. As the industry increasingly moves towards more collaborative and integrated project delivery methods, the use of cloud-based tools will become even more critical. Construction companies should focus on adopting these tools to facilitate better coordination among project teams, reduce the risk of miscommunication, and ensure that all stakeholders are aligned throughout the project lifecycle.

Finally, while PMS Implementation has a comparatively smaller impact on project efficiency, it remains an essential component of effective project management. Construction firms should continue to invest in and refine their Project Management Systems to ensure that they can effectively manage the complexities of modern construction projects. By integrating PMS with BIM and Cloud Collaboration, companies can create a holistic project management framework that supports efficient and successful project delivery.

Limitations and Future Research

While this study provides important insights into the factors influencing construction project efficiency in Riau, it is not without limitations. The use of a purposive sampling technique and reliance on self-reported data may introduce biases that could affect the generalizability of the findings. Future research could address these limitations by employing random sampling methods and incorporating objective measures of technology use.

Additionally, while this study focuses on the impact of technological tools on project efficiency, other factors such as organizational culture, leadership, and external environmental conditions may also play a significant role. Future studies could explore these additional variables to provide a more comprehensive understanding of the drivers of construction project efficiency.

CONCLUSION

This study provides empirical evidence that the implementation of Project Management Systems, Building Information Modeling (BIM) technology, and Cloud Collaboration significantly enhances construction project efficiency in Riau, Indonesia. Among these factors, BIM technology was found to have the most substantial impact, highlighting its critical role in improving design accuracy, coordination, and overall project outcomes. Cloud Collaboration also showed a strong positive effect, emphasizing the importance of real-time communication and data sharing in managing construction projects effectively. Although the impact of PMS implementation was slightly less pronounced, it remains a vital component of project management that contributes to project efficiency by providing a structured framework for planning and execution.

The findings suggest that construction firms in Riau should prioritize the adoption and integration of these advanced technologies to achieve better project performance. By investing in BIM, Cloud Collaboration, and PMS, companies can enhance their ability to deliver projects on time, within budget, and to the required quality standards. However, successful implementation requires careful planning, adequate training, and ongoing support to maximize the benefits of these technologies.

This study also acknowledges its limitations, including the use of purposive sampling and self-reported data, which may affect the generalizability of the results. Future research should consider exploring additional factors that influence construction project efficiency, such as organizational culture, leadership, and external environmental conditions, to provide a more comprehensive understanding of the drivers of success in construction projects.

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