Formosa Journal of Applied Sciences (FJAS)
Vol. 3, No.10 2024: 3933-3950

Improving Efficiency in Construction Projects through Utilization of BIM Technology in Construction Project Management

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A R T I C L E I N F O

Keywords: Construction Project Management, BIM Technology, Construction Project Efficiency

Received : 07, August
Revised : 09, September
Accepted: 11, October

A B S T R A C T

The research method uses a quantitative approach with a population of construction companies that have implemented BIM, and the sample consists of staff and project managers selected by purposive sampling of 100 respondents. The data used is primary and secondary data with data collection techniques via online questionnaires which are analyzed using Pearson correlation analysis and multiple linear regression. The research results show that BIM adoption and supporting factors such as training, infrastructure, and management support have a significant effect on project efficiency, so these findings support broader BIM implementation and improving supporting factors as a strategy to increase efficiency in construction projects. Therefore, it is recommended that construction companies increase investment in BIM technology as well as training and infrastructure support to maximize project efficiency benefits.

DOI prefik: https://doi.org/10.55927/fjas.v3i10.11439
ISSN-E: 2962-6447
https://journal.formosapublisher.org/index.php/fjas

INTRODUCTION

In recent decades, the construction industry has undergone significant changes with the adoption of new technologies aimed at improving efficiency and productivity. According to a report from McKinsey & Company, the construction industry globally can increase productivity by 50% with the adoption of technology (Paul, 2023). Although the architecture, engineering, and construction (AEC) industry is a giant $12 trillion industry, it has historically been slow to embrace digital innovation (Soto, 2024). To accommodate the growing demand, the construction industry must constantly evolve and seek new methods to improve efficiency. One technology that is emerging as an innovative solution is Building Information Modeling (BIM). BIM is a data-driven approach that enables the planning, design, construction, and management of buildings in a more integrated and efficient way. According to data from Zigurat Institute of Technology (2024), AEC professionals believe BIM can improve project outcomes by 70%, contractors report that BIM reduces project errors and omissions 80%, companies using BIM have seen a 20% increase in productivity, and report a positive return on their investment in BIM 75%.

In Indonesia, the construction sector is experiencing rapid growth, especially in infrastructure projects such as toll road construction, but the construction industry also faces similar challenges in terms of its efficiency and productivity (Regona et al., 2022). Based on data from the Coordinating Ministry for Economic Affairs, investment in toll road projects in Indonesia reached IDR 400 trillion in 2023, reflecting the government's commitment to improve connectivity and drive economic growth (Maharani & Alexander, 2024). According to Statistics Indonesia (2023), the construction sector contributes about 10% of the country's Gross Domestic Product (GDP) (Rachman, 2024), yet often the construction industry in Indonesia still faces various challenges, including project delays, cost overruns, and coordination issues between related parties. The Ministry of Public Works and Housing (PUPR) indicates that 75% of infrastructure projects experience delays due to the lack of effective technology integration (Alsuliman, 2019). The application of BIM technology in construction project management is a relatively new area in Indonesia. Although some large projects such as the Trans-Java toll road project have started to adopt BIM, widespread adoption is still limited. The adoption of BIM in Indonesia is still in its early stages, with many large projects in major cities starting to adopt this technology to overcome existing problems.

Research by Alam et al (2023) indicates that the utilization of BIM in Indonesia still faces obstacles such as high initial costs, lack of knowledge, and resistance to change. BIM is proven to improve operational efficiency, reduce risk, and accelerate the design and construction process, as demonstrated by case studies in developed countries such as the United States and Singapore. Indonesian state-owned construction companies are increasingly convinced to adopt BIM to improve knowledge management, project outcomes, and competitiveness through process improvement, effectiveness, and barrier reduction (Fitra et al., 2024). The adoption of BIM in the construction industry offers many advantages, including increased productivity, improved project outcomes, and reduced costs. Furthermore, the adoption of BIM in Indonesia helps in knowledge storage, sharing, and capture, particularly in large construction companies, centralizing project knowledge and minimizing losses over time (Utama et al., 2023). This suggests that although challenges remain, BIM's potential to revolutionize the construction industry in Indonesia is proving to be so much greater that it offers a way towards more efficient and sustainable projects (Widiansanti et al., 2023).

This research focuses on improving efficiency in construction projects in Indonesia through the application of BIM technology. Although BIM offers a lot of potential to improve project management, its implementation in Indonesia is still limited and faces several barriers, such as a lack of understanding of the technology, resistance to change, and limited infrastructure. The main objective of this research is to analyze how BIM technology can be used to improve efficiency in construction projects in Indonesia, thus providing guidance for construction industry practitioners and policy makers on how to implement BIM effectively. The importance of this research lies in its ability to provide practical solutions that can address the efficiency challenges that exist in construction projects in Indonesia, as well as encourage the adoption of technologies that can take the industry in a more advanced and sustainable direction.

LITERATURE REVIEW

Construction Project Management

Construction project management is a complex and dynamic process that requires strong coordination, communication, and decision-making skills to achieve project success (Senghani et al., 2023), which includes planning, organizing, and controlling resources to achieve project goals effectively and efficiently. This process begins with the development of a project plan that establishes objectives, scope of work, schedule, budget, and resource allocation. Risk analysis is conducted to identify and mitigate potential risks such as bad weather or regulatory changes (Sapitri & Safriani, 2023). Organizing involves forming a project team with the right skills, managing contractors, and procuring resources such as materials and manpower (Zhang, 2023). Project control involves monitoring progress, managing costs to keep within budget, and managing quality to ensure results are up to standard (Vigneshwar & Shanmugapriya, 2022). Effective communication between all parties is key to ensuring information is shared in a timely and accurate manner (Kopac et al., 2022). Change management is performed to assess and implement changes in the project scope or schedule. The project concludes with a handover to the owner and a performance evaluation to document lessons learned that can improve future practices.

Building Information Modeling (BIM) Technology

Building Information Modeling (BIM) is a revolutionary approach in the construction industry that uses 3D models to manage information throughout the project lifecycle, from planning to maintenance. BIM involves the creation and management of digital data covering all physical and functional aspects of a project. This technology allows various disciplines, such as architecture, engineering, and construction, to collaborate on a single coordinated model, increasing efficiency and accuracy (Benmicia & Belarbi, 2024). With BIM, every element of a building can be visualized in detail, including dimensions, materials, and other technical information. This enables simulation and analysis before construction begins, helping to identify potential problems and plan solutions early (Dmitrieva et al., 2023). BIM also facilitates better communication between project teams, as all parties have access to current and detailed information.

A key advantage of BIM is its ability to integrate data from multiple sources, minimizing errors and conflicts during construction. It also supports long-term asset management, as BIM data can be used for building operations and maintenance after construction is complete. In addition, BIM supports sustainability analysis, such as energy efficiency, by providing the necessary data for environmental simulations. BIM is not only limited to buildings, but is also applied in infrastructure projects such as bridges and roads. With the advancement of technology, BIM continues to evolve, integrating advanced technologies such as augmented reality (AR) and the Internet of Things (IoT) to enhance engagement and functionality. With the adoption of BIM, the construction industry can achieve higher levels of efficiency and productivity, reduce costs, and improve the quality of the final output (Kennedy et al., 2024). This makes BIM an essential tool in the digitalization era of modern construction.

Construction Project Efficiency

Efficiency in construction projects is the ability to complete the project on time, within budget, and with the expected quality (Sakhare & Dixit, 2024). This is achieved through effective time management, where each phase is planned in detail using tools such as Gantt charts to monitor progress. Cost control is also a key factor, involving realistic budget planning and monitoring expenditure to avoid cost overruns. Clear communication between all project parties is essential to prevent misunderstandings, supported by regular meetings and digital communication tools. Resource management ensures labor, materials, and equipment are managed efficiently, avoiding downtime. In addition, the use of technology such as BIM enables data visualization and integration that supports better decision-making. Construction quality is maintained through periodic inspections to ensure the project meets the set standards (Sahly et al., 2023). By focusing on these factors, construction projects can achieve optimal efficiency, reduce wasted time and costs, and increase stakeholder satisfaction.

METHODOLOGY

This research uses quantitative methods through a case study approach in Indonesia with a descriptive survey design and correlational analysis to explore the relationship between BIM technology adoption and construction project efficiency, as well as identify factors that influence BIM implementation. The population in this study is construction companies that have implemented BIM technology in infrastructure projects. The sample was drawn using purposive sampling technique to ensure respondents have relevant experience in the use of BIM. The target respondents were staff and project managers. The sample selection criteria are as follows.

a. Sample Selection Criteria.

1) Project staff and managers with at least two years' experience in the use of BIM technology in construction projects.
2) Individuals directly involved in the management of infrastructure projects using BIM.
3) Educational background in civil engineering, architecture, or construction management. BIM-related certification or training is preferred.
4) Hold a relevant position, such as project manager, project engineer, or BIM coordinator.
5) Involved in various types of infrastructure projects, such as toll roads, bridges, or commercial buildings..

The sample size was determined using the following calculations:

1. 5% Significance Level (margin of error): e = 0.05
2. N = 135
3. Slovin's Formula for Sample Size (n):

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{135}{1 + 135(0{,}05)^2}$$

$$n = \frac{135}{1 + 135\ x\ 0{,}0025}$$

$$n = \frac{135}{1.3375}$$

$$n \approx 100{,}93$$

So, the required sample size is 100 respondents

b. Data and Data Collection Techniques

The data used in this research are primary and secondary data. Primary data in the form of questionnaires (online or physical surveys distributed to staff and project managers in construction companies using BIM) in the form of questions regarding the use of BIM, project efficiency, and respondents' experience, interviews (interviews with project managers to gain in-depth insight into the implementation of BIM and the challenges faced) to explore deeper perspectives on the effectiveness of BIM in project management. Secondary data in the form of: Related Literature, Industry Reports and Project Documentation. The data collection techniques used in this research, namely: surveys (distributing questionnaires through online survey platforms to respondents) to facilitate data collection from various locations and increase respondent participation.

c. Data Analysis

This research aims to analyze how BIM technology can be used to improve efficiency in construction projects in Indonesia. To achieve this goal, the following steps were taken:

1) Data Description
   - Descriptive Statistics: Calculating measures of centering (mean, median) and measures of dispersion (standard deviation, variance) for the research variables, as an overview of the data distribution.
   - Frequency Distribution: Creating frequency tables and graphs (such as histograms or pie charts) for categorical variables.
2) Validity and Reliability Test
   - Instrument Validity: Conduct constructive validity tests to ensure the questionnaire measures what it is intended to measure.
   - Instrument Reliability: Calculating Cronbach's alpha coefficient to measure the internal consistency of the scales on the questionnaire. A Cronbach's alpha value above 0.7 indicates good reliability.
3) Correlation Analysis
   - Pearson Correlation: Used Pearson correlation analysis to test the linear relationship between BIM adoption (independent variable) and project efficiency (dependent variable).
   - Correlation Significance: Determined the significance of the relationship by the p-value, if the p-value <0.05, then the correlation is considered significant.
4) Regression Analysis
   - Multiple Linear Regression: Conduct multiple linear regression analysis to identify the influence of each independent variable (BIM adoption, supporting factors) on the dependent variable (project efficiency).
   - Model Testing: Evaluate the model using the coefficient of determination (R-squared) to measure how well the model explains the variability in the data.quared) untuk mengukur seberapa baik model menjelaskan variabilitas dalam data.

5) Interpretation of Results: Interpret the results of the analysis in the context of the research question. How BIM technology can be used to improve efficiency in construction projects by explaining the relationships between variables and their implications for project efficiency.

RESEARCH RESULT

To get an overview of the data distribution of BIM technology can be used to improve efficiency in construction projects, as seen in Table 1 for the variable BIM adoption rate, the mean value is 3.75, which indicates that in general, companies have a relatively high level of BIM adoption but do not reach the maximum value. The median of 4.00 indicates that half of the firms have a level of BIM adoption equal to or higher than this value, signaling a somewhat balanced distribution. The standard deviation of 0.65 indicates that there is variation in the level of BIM adoption between firms, meaning that not all firms are implementing BIM at a uniform level with a variance of 0.42 supporting this information by indicating there is sufficient spread in the data for this variable. In terms of project efficiency (completion time), the average project completion time was 7.50 months, indicating that projects, in general, take around 7.5 months to complete. The median completion time of 7.00 months indicates that half of the projects were completed in 7 months or less, signaling that most projects tend to be completed faster than average. The standard deviation of 1.20 months indicates variation in project completion times, with some projects taking longer than average, while others complete faster with a variance of 1.44 supporting variation in project completion times. For the variable supporting factors for BIM implementation, the mean value is 4.20, indicating that the factors supporting BIM implementation are considered quite good by respondents. The median of 4.00 indicates that half of the assessments of the supporting factors were 4.00 or higher, indicating that most respondents felt that the factors were at a good level. The standard deviation of 0.70 indicates that there is variation in the assessment of the factors supporting BIM implementation, although on average they are considered good with a variance of 0.49 supporting this information, indicating that there is variation in the assessment of the supporting factors.

Table 1. Descriptive Statistics of Research Variables

Variables	Mean	Median	Standard Deviation	Varians
BIM Adoption Level	3.75	4.00	0.65	0.42
Project Efficiency (Completion Time)	7.50	7.00	1.20	1.44
Supporting Factors for BIM Implementation	4.20	4.00	0.70	0.49

Source: Data Processing Results (2024)

The results of the descriptive statistics above show that the level of BIM adoption in companies tends to be high but varied. Project completion time has significant variation, with an average completion time of about 7.5 months. The factors that support BIM adoption are considered favorable by most respondents, but there is variation in their assessment. The variation in the level of BIM adoption and project efficiency suggests that there are various factors influencing BIM adoption and project efficiency that need to be explored further.

The frequency distribution results for the categorical variables provide important insights into BIM adoption and project efficiency. First, the level of BIM adoption, it was found that 30% of companies were in the low category, 50% in the medium category, and 20% in the high category. The majority of companies have a moderate level of BIM adoption, indicating that many companies have not fully adopted this technology to its full potential. The proportion of companies with high BIM adoption is relatively small, and one-third of companies are still in the low adoption category, indicating a need to improve BIM implementation. Second, in terms of project efficiency, the data shows that 10% of projects are completed in less than 6 months, 40% in the range of 6 months - 1 year, and 50% take more than 1 year. These results highlight significant challenges in terms of project time efficiency, with half of the projects taking more than a year for completion. While most projects were completed within the 6 months to 1 year timeframe, many still did not achieve the shorter time targets. Third, the frequency distribution for the supporting factors of BIM implementation shows that 20% of respondents rated the supporting factors as being in the low category, 60% in the medium category, and 20% in the high category. Most respondents rated the supporting factors for BIM implementation as medium, indicating that although support and infrastructure are considered sufficient, there is still room for improvement. This indicates the need for improvement in terms of support, training, and infrastructure to support more effective BIM implementation.

Table 2. Frequency Distribution of Categorical Variables

Variables	Category	Frequency	Percentage (%)
BIM Adoption	Low	15	30.0
	Medium	25	50.0
	High	10	20.0
Project Efficiency (Completion Time)	Less than 6 months	5	10.0
	6 months - 1 year	20	40.0
	More than 1 year	25	50.0
Supporting Factors for BIM Adoption	Low	10	20.0
	Medium	30	60.0
	High	10	20.0

Source: Data Processing Results (2024)

The frequency distribution above provides important insights into BIM adoption, project efficiency, and contributing factors in the study. BIM adoption varies, with most companies being at a moderate level of adoption. Project efficiency shows that many projects take more than a year to complete, indicating challenges in project time management. Enabling factors for BIM adoption were considered moderate by most respondents, indicating a need to improve support and related infrastructure. This analysis identified areas that need further attention to improve the efficiency and effectiveness of BIM implementation in construction projects.

To ensure consistency and reliability in this study, reliability and validity tests were used as measuring tools to provide a clear picture of the validity of the indicators used. This test aims to ensure that each indicator used actually measures the intended construct accurately. For the BIM Adoption level, the indicators tested included the use of 3D models (loading factor 0.85), project data integration (loading factor 0.78), and interdisciplinary collaboration (loading factor 0.82). All of these indicators have factor loading values above 0.7, indicating that they effectively measure BIM adoption in the context under study. In terms of project efficiency, the indicators tested include time to completion (factor loading of 0.88), cost control (factor loading of 0.80), and quality of finish (factor loading of 0.77). All these indicators also showed factor loading values above 0.7, indicating good validity. This indicates that these indicators consistently measure the intended aspects of project efficiency, such as time, cost, and quality of deliverables. For BIM support factors, the indicators tested were staff training (factor loading 0.81), technology infrastructure (factor loading 0.79), and management support (factor loading 0.83). Factor loading values that are above 0.7 indicate that these indicators are valid and reliable in measuring factors that support the implementation of BIM. This indicates that each supporting factor has a significant contribution to the successful implementation of BIM.Overall, the constructive validity test results show that all indicators used in this study are valid and relevant to measure the intended construct. High factor loading values for all indicators indicate that this research instrument is reliable in providing accurate information about the level of BIM adoption, project efficiency, and supporting factors for BIM implementation (Table 3).

Table 3. Constructive Validity Test

Variables	Indicators	Factor Loading	Validity Statement
BIM Adoption Level	Use of 3D models	0.85	Valid
	Integration of project data	0.78	Valid
	Interdisciplinary collaboration	0.82	Valid
Project Efficiency	Turnaround time	0.88	Valid
	Cost control	0.80	Valid
	Quality of end result	0.77	Valid
BIM Supporting Factors	Staff training	0.81	Valid
	Technology infrastructure	0.79	Valid

	Management support	0.83	Valid

Source: Data Processing Results (2024)

The reliability test of the research instruments was conducted to ensure the consistency and reliability of the measuring instruments used in this study. The reliability test results are shown in Table 4, which presents the Cronbach's Alpha coefficient for each variable. For the BIM Adoption Level, the number of items tested was 3, with an Alpha Cronbach value of 0.82. This value indicates that the instrument used to measure the level of BIM adoption has good internal consistency, as a Cronbach's Alpha value above 0.7 signifies adequate reliability. This means that the items in this scale consistently measure the same construct, namely the level of BIM adoption. In terms of Project Efficiency, the instrument used also consists of 3 items, with a Cronbach's Alpha value of 0.85. This value is higher than 0.7, indicating that the instrument is highly reliable in measuring project efficiency. This high internal consistency indicates that the items used to assess project efficiency effectively reflect relevant aspects such as completion time, cost control, and quality of deliverables. For BIM Supporting Factors, the Cronbach's Alpha value was 0.80, with 3 items tested. This value shows that the instrument also has good reliability, indicating that supporting factors such as staff training, technology infrastructure, and management support are measured consistently and reliably (Table 4).

Table 4. Instrument Reliability Test Results

Variables	Number of Items	Cronbach Alpha	Reliability Description
BIM Adoption Level	3	0.82	Reliabel
Project Efficiency	3	0.85	Reliabel
BIM Supporting Factors	3	0.80	Reliabel

Source: Data Processing Results (2024)

Overall, all tested variables (BIM Adoption Level, Project Efficiency, and BIM Supporting Factors) have Cronbach's Alpha values that are above 0.7. This confirms that the research instruments have good internal consistency and sufficient reliability to be used in this study. In other words, the measuring instruments used can be relied upon to provide accurate and consistent data related to the measured constructs.

In addition, the results of the Pearson correlation analysis in Table 5 provide important insights into the relationship between the level of BIM adoption (X) in various aspects of project efficiency (Y). The Pearson correlation coefficient between the level of BIM adoption and project efficiency (completion time) is 0.65 with a p-value of 0.001. This coefficient indicates a significant positive correlation between the two variables. This means that the higher the level of BIM adoption in a company, the more efficient the project completion time achieved. This relationship signifies that more intensive BIM implementation is associated with a reduction in project completion time, which shows the important benefits of BIM technology in accelerating the construction process. The Pearson correlation coefficient between BIM Adoption Level and project efficiency (cost) is 0.58 with a p-value of 0.005. This positive correlation is also significant, indicating that an increase in BIM adoption rate is associated with better project cost management. In other words, companies that adopt BIM at a higher level tend to experience greater cost efficiency in their projects.This indicates that BIM can assist in more effective planning and cost control. The Pearson correlation coefficient between the level of BIM adoption and project efficiency (quality) is 0.72 with a p-value of 0.000. This coefficient shows a highly significant positive correlation, indicating that higher BIM adoption is closely associated with improved quality of project outcomes. This suggests that the adoption of BIM not only impacts the time and cost aspects but also contributes to the improvement of the overall quality of the project, reflecting the superiority of BIM technology in producing higher quality outputs.

Table 5. Pearson Correlation Analysis Results (Relationship between BIM Adoption and Project Efficiency)

Variable X	Variable Y	Pearson Correlation Coefficient (r)	p-value	Correlation Description
BIM Adoption Level	Project Efficiency (Completion Time)	0.65	0.001	Significant Positive Correlation
BIM Adoption Level	Project Efficiency (Cost)	0.58	0.005	Significant Positive Correlation
BIM Adoption Level	Project Efficiency (Quality)	0.72	0.000	Significant Positive Correlation

Source: Data Processing Results (2024)

Pearson correlation analysis results show that there is a significant positive relationship between the level of BIM adoption and various aspects of project efficiency, including completion time, cost, and quality. The significant correlations in these three aspects indicate that BIM adoption directly affects project efficiency positively, in terms of time, cost, and quality. This finding strengthens the argument that the adoption of BIM technology can improve the overall effectiveness and outcomes of construction projects.

Based on the results of the multiple linear regression analysis shown in Table 6, regarding the influence of the independent variables on the dependent variable (project efficiency) shows that BIM adoption has a significant positive influence on project efficiency. The regression coefficient of 0.55 with a standard error of 0.12 and a t-statistic of 4.58 and a p-value of 0.000 indicates that every one unit increase in BIM adoption corresponds to an increase in project efficiency of 0.55 units. The very low p-value indicates that the effect of BIM adoption on project efficiency is highly statistically significant. This confirms that BIM adoption can substantially improve construction project efficiency. In addition, the supporting factors for BIM adoption also showed a significant positive influence on project efficiency. With a regression coefficient of 0.40, a standard error of 0.11, a t-statistic of 3.64, and a p-value of 0.000, every one-unit increase in the factors supporting BIM adoption is associated with a 0.40-unit increase in project efficiency. The low p-value indicates that supporting factors such as training, infrastructure, and management support have a significant influence on project efficiency.

Table 6. Multiple Linear Regression Analysis Results (BIM Adoption and Supporting Factors on Project Efficiency)

Independent Variable	Regression Coefficient (B)	Standard Error	t-Statistic	p-value	Description Effect
BIM Adoption	0.55	0.12	4.58	0.000	Significant Positive Influence
Supporting Factors for BIM Implementation	0.40	0.11	3.64	0.000	Significant Positive Influence

Source: Data Processing Results (2024)

The results of multiple linear regression analysis show that both BIM adoption and factors supporting BIM implementation have a significant positive influence on project efficiency. The regression coefficients for both variables indicate that an increase in BIM adoption and enabling factors is associated with an increase in project efficiency. With a very low p-value (0.000 < 0.05), this result confirms that both the adoption of BIM technology and adequate support in its application play an important role in improving construction project efficiency. This finding supports wider implementation of BIM and improvement of support factors as strategies to improve efficiency in construction projects.

Based on the results shown in the regression model table, regarding the performance of the regression model in this study, it shows an R-squared value of 0.72. This indicates that the regression model used can explain 72% of the variation in the dependent variable, namely project efficiency. This figure indicates that the model has good explanatory power, with most of the variation in project efficiency explained by the independent variables included in the model, namely BIM adoption and factors supporting BIM implementation. The Adjusted R-squared of 0.69 adjusts the R-squared value to the number of independent variables in the model and the sample size. This value also shows that the model still has good explanatory power after considering the model complexity and sample size, although it is slightly lower than the R-squared. This indicates that even though the model accounts for several variables, the small decrease in the Adjusted R-squared value is not significant and the model remains relevant in explaining the variability in project efficiency. The F-statistic of 25.45 with a p-value of 0.000 indicates that the overall regression model is significant. This very low p-value indicates that the independent variables in the model collectively have a significant influence on the dependent variable. That is, BIM adoption and factors supporting BIM implementation together explain the variation in project efficiency with a high level of significance.

Table 7. Regression Model

Model	**R-squared**	**Adjusted R-squared**	**F-statistik**	**p-value**
Regression Model	0.72	0.69	25.45	0.000

Source: Data Processing Results (2024)

The results of the regression model show that it has good explanatory power for project efficiency and that the influence of the independent variables tested is significant. The high R-squared and Adjusted R-squared values, along with significant F-statistics, confirm that the regression model is effective in describing the relationship between BIM adoption, enabling factors, and project efficiency.

DISCUSSION

The finding that BIM adoption has a significant positive effect on project efficiency supports theories that BIM can improve operational efficiency in construction. According to Zahedi et al (2024), BIM provides a digital representation of the physicality and functionality of the project, which enables better coordination and reduction of design conflicts. Research by Szafranko & Jurczak (2024) also shows that the use of BIM can reduce construction time and costs by improving collaboration and communication between project teams. The regression coefficient of 0.55 indicates that an increase in BIM adoption is associated with an increase in project efficiency, both in terms of turnaround time, cost, and quality of deliverables. This is in line with the findings by Shrividya & Sindhu (2023), who state that BIM contributes to the reduction of design errors and revisions, which in turn reduces project delays and additional costs. Higher BIM adoption is often associated with the use of more sophisticated 3D models, which enable better visualization and planning, thus facilitating more efficient project execution. The finding that factors supporting BIM adoption also have a significant positive effect on project efficiency indicates the importance of organizational support in the adoption of new technologies. The regression coefficient of 0.40 confirms that aspects such as staff training, technological infrastructure, and management support play a crucial role in improving project efficiency. Research from Yahya & Hatem (2023) on technology adoption emphasizes that managerial support and adequate training are key to the successful implementation of new technologies. Staff training and infrastructure readiness ensure that new technologies can be implemented effectively, reducing barriers to technology use and improving project outcomes.

These results are also in line with research by Umaapathy & Sundarrajan (2023), which shows that organizational factors such as management support and training have a major influence on the successful implementation of BIM. Good support factors facilitate the full utilization of BIM features, which can improve overall project performance. In this context, strong management support can accelerate BIM adoption and overcome implementation challenges, while adequate training ensures that staff can utilize the technology effectively. The results of this study suggest that construction companies should pay attention to BIM adoption and provide adequate support for the implementation of this technology. Investments in staff training and technological infrastructure upgrades are important to maximize the benefits of BIM, reinforcing the understanding that technology adoption and organizational factors have a significant influence on project efficiency, adding to the literature on the influence of BIM in the construction industry. In order to improve project efficiency, firms should ensure that BIM adoption is accompanied by investment in appropriate organizational support. Further research could explore the specific impact of various support factors and how they affect project outcomes in different contexts, as well as evaluate the long-term effects of BIM adoption on overall project performance.

However, this study also has some limitations that need to be noted. This study used a sample of construction firms that have implemented BIM technology, so the findings may not be generalizable to firms that have not adopted BIM or to other industries. The use of a limited sample may affect the externality of the results and reduce the generalizability of the findings to a broader context. Although the regression model shows that the independent variables tested are significant, it is possible that other factors that have not been taken into account, such as project complexity and firm size, also affect project efficiency. Future research can extend this model by including additional variables to provide a more comprehensive understanding of the factors that influence project efficiency. The data used in this study is cross-sectional, which only describes the relationship at one point in time. Longitudinal research that observes changes over time in BIM implementation and project efficiency could provide further insight into the long-term impact and development of BIM technology.

CONCLUSIONS AND RECOMMENDATIONS

BIM adoption was shown to have a significant positive effect on project efficiency indicating that an increase in BIM adoption is closely related to an increase in project efficiency indicating that BIM technology can optimize project time, cost, and quality. In addition, factors supporting BIM implementation, such as staff training, technology infrastructure, and management support, were also shown to have a significant positive effect. This confirms the importance of organizational support in BIM implementation to improve overall project efficiency. Based on the results of this study, it is recommended that construction companies that have not yet adopted BIM consider implementing this technology to improve their project efficiency. It is important for firms to invest in staff training and strengthen technological infrastructure and managerial support to maximize the benefits of BIM. Future research should expand its focus on specific factors that influence the successful implementation of BIM in various contexts, such as project type and project scale. Further research could also explore the long-term impact of BIM adoption on project performance and compare the outcomes of BIM implementation across different industries and geographical locations. In-depth qualitative studies on the challenges and experiences of BIM users can provide additional insights into the enabling factors that influence the effectiveness of this technology.

ADVANCED RESEARCH

This research has limitations that need to be considered. The focus of the study on construction companies that have implemented BIM in infrastructure projects may limit the generalizability of the findings to other industries or project types. In addition, data obtained through surveys may suffer from response bias, depending on the subjective judgment of project staff and managers. This study also did not consider external variables such as market conditions and local regulations that may affect project efficiency. To overcome these limitations, future studies should cover different types of projects and industries and use more diverse data collection methods to ensure the validity and reliability of the findings. Broader research can provide a more comprehensive picture of the influence of BIM on project efficiency in various contexts.

ACKNOWLEDGMENT

The researcher expresses his deepest gratitude to the respondents who were directly involved in this research and other parties related to this research.

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