AJEMB
AMERICAN JOURNAL OF ECONOMIC AND MANAGEMENT BUSINESS

American Journal of Economic and Management Business
e-ISSN: 2835-5199
Vol. 4 No. 8 August 2025

Optimization of 300 Feet Deck Barge Project Management Through Comparison of BIM and Conventional Methods at PT. Sky Batam

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Abstract

Deck barge construction projects are vital to the shipbuilding industry, requiring efficient time and cost management. Conventional project management often faces challenges such as delays, budget overruns, and poor coordination. Digitalization through Building Information Modeling (BIM) offers an integrated approach by combining 3D design, scheduling (4D), and cost estimation (5D) in real time. This study compares conventional and BIM-based project management on a 300-foot deck barge built at PT. SKY Pulau Batam shipyard. Using purposive sampling, data from actual project documentation (conventional) and BIM re-simulation was analyzed via descriptive statistics and independent t-tests. Results show BIM significantly improves project efficiency. The average duration with BIM was 89 days versus 107.4 days with the conventional method (Sig. (2-tailed) < 0.001). Budget deviation with BIM was eliminated, compared to 6–10% deviation conventionally. Technical documentation and coordination also improved markedly, with drawing revisions dropping from 21.2 to 4.2 and reduced delayed RFIs ($p < 0.001$). The study concludes BIM is more than a visual tool; it measurably enhances efficiency in time, cost, and documentation. These findings support strategic recommendations for accelerating digital transformation in the national shipbuilding industry's project management.

Keywords: Project Management, BIM, Deck Barge, Time Efficiency, Cost Estimation, Shipyard, Digitalization.

INTRODUCTION

Indonesia's shipbuilding industry plays an important role in realizing the vision of the Archipelagic World, especially through the development of maritime infrastructure, marine logistics, and other supporting industries. Based on data from the Central Statistics Agency (BPS) in 2023, the export value of Indonesia's ships and floating structures reached more than USD 1.2 billion, with significant contributions from shipyards in Batam and Surabaya. However, in reality, the shipbuilding process, especially specialized jobs such as deck cargo barges, continues to face a number of classic challenges that limit efficiency: unreasonable delays in project completion, large cost overruns, poor interdepartmental coordination, and discrepancies between actual designs and products (Setyawan & Prabowo, 2020).

This research aims to address specific objectives that have been clearly defined: (1) to quantitatively measure the time efficiency differences between conventional and BIM methods in

300-foot deck barge construction, specifically comparing project duration in days and analyzing statistical significance; (2) to evaluate cost efficiency by measuring budget variance percentages and actual expenditure differences between both approaches; and (3) to assess documentation efficiency through quantifying drawing revisions, RFI (Request for Information) frequency, and coordination quality metrics between project teams.

Previous research has shown varying degrees of BIM effectiveness across different construction contexts, but significant gaps remain in shipbuilding applications, particularly in Indonesian maritime industry settings. While studies by Chen & Luo (2020) demonstrated BIM benefits in Chinese shipyards and Kim et al. (2022) showed positive results in Korean maritime projects, limited research has specifically examined BIM implementation challenges and benefits within Indonesian shipbuilding industry contexts. Furthermore, most existing studies focus on large-scale commercial vessels rather than specialized craft like deck barges, creating a knowledge gap in understanding BIM applicability for mid-scale maritime construction projects that represent a significant portion of Indonesia's shipbuilding output.

Most shipyards in Indonesia still adopt a traditional project management style, which is based on physical documents and relies on fragmented systems for reporting and separating the digital design stage from the technical implementation on site. In such scenarios, the risk of design errors increases, communication remains out of sync, and the validation process takes time. Consequently, these issues lead to increased actual costs and project delays (Wijaya & Santoso, 2021).

Wijaya & Santoso (2021) show that the limitations of centralized information platforms have been the main reason for the emergence of inconsistencies between divisions and slow decision validation processes. These challenges illustrate problems in three main focus areas of the study: project time, project cost, and quality of technical documentation.

Project delays for conventional methods and partial BIM can be obtained from the documentation of the barge project of PT. *SKY* on Batam Island from 2022 to 2024, as seen in Table 1 below:

Table 1. Average Deck Barge Project Delays

Project Year	Target Duration (days)	Realization (days)	Time Deviation	Information
2022	90	**107.4**	+17.4 days	Conventional
2023	90	93.8	+3.8 days	BIM Pilot (Parsial)
2024	90	89	-1 day	Full BIM

Source: Project documentation of PT. SKY, processed by researchers (2025)

This table shows a comparison between the target project duration and the actual realization of deck barge construction for three consecutive years (2022–2024) at PT. SKY Batam Island. In 2022 and 2023, the project still uses conventional methods and experienced significant delays of 23 days and 12 days, respectively. However, in 2023, when BIM began to be partially implemented, project delays decreased drastically to just 4 days. This indicates that the use of BIM contributes to the efficiency of the project implementation duration. Less controlled project costs are also an obstacle. There is an average actual cost overrun estimated at 10–18% compared to the

Cost Budget Plan (RAB). One of the main causes is late design revisions, rework, and insynchronization between technical sections (Source: PT. SKY, processed by researchers (2025)). Project documentation, whether in the form of working drawings, technical specifications, or progress reports, is often out of sync between sections. The findings of the document audit showed that there were an average of 20–25 design revision items per project and many Requests for Information (RFI) between divisions that were not answered in a timely manner.

Table 2. Sample Technical Documentation Findings

Year	Number of Image Revisions (Average)	Number of Pending RFIs (Average)	Consequences of Late Revision
2022	21.2	15	Images out of sync, many questions are pending
2023	11.2	7.2	Efficiency starts to increase due to job volume modeling
2024	4.2	2.2	Conflict-free projects, real-time digital documentation

Source: Engineering Department of PT. SKY (2024)

This table shows the number of engineering drawings revisions and the number of pending information requests (RFIs) on three deck barge projects in 2022–2024 at PT. SKY Batam Island. In 2022 and 2023 projects that use conventional methods, the number of revisions and RFIs is quite high and has a direct impact on construction delays, such as disruption of bottom installation and errors in the stiffener structure. However, in the 2024 project that starts using BIM partially, the number of revisions and RFIs decreases significantly, and coordination between teams becomes smoother. This shows that the application of BIM has the potential to improve the quality of documentation and the efficiency of technical communication.

In project management theory, the success of project execution will be greatly influenced by the system's ability to integrate information into realistic planning and collaborative execution (Kerzner, 2017). Therefore, technological innovations that answer this challenge are Building Information Modeling (BIM). BIM is a three-dimensional (3D) model-based collaborative modeling method that can be extended to consider time (4D) and cost (5D) and serves as a multifunctional integration platform among all project stakeholders.

Eastman et al. (2018) explain that BIM makes the process more structured and efficient because it gathers all design, construction, and operational information into a single digital model, which is available in real-time. To reduce design and rework conflicts, improve decision-making speed, and improve overall efficiency. Empirical evidence by Eze et al. (2023) shows that the use of BIM in complex construction projects can improve project management efficiency by up to 30% and accelerate project completion time by up to 20%. However, in Indonesia, the implementation of BIM is still relatively limited. According to a report by the Ministry of PUPR (2022), the implementation of BIM in national projects is still below 15%, with the main obstacles in the form of the availability of trained workers, limited hardware and software, and the absence of national laws and regulations governing the use of BIM as a whole. Widjojo & Setiawan (2022) also emphasized the importance of local studies that will demonstrate the benefits of BIM in the local context to spur wider adoption for industrial applications in Indonesia.

In this case, PT. SKY Batam Island, as one of the shipyards in Indonesia, faces challenges like this. The current 300-foot deck barge construction project is said to be very complex in design and execution. Time and cost efficiency parameters demand an entirely different approach that is more adaptive and data-driven in project management. Therefore, the application of building information modeling as an innovative approach is considered highly relevant to overcome these challenges.

This research is important and relevant to be conducted for several fundamental reasons:

1. The gap between industrial needs and existing conditions: most national shipyards have not yet implemented a digital approach in their project management, even though the need for time and cost efficiency is constantly increasing.
2. Lack of local empirical studies: Research on BIM in Indonesia is still very limited, especially those that directly compare conventional methods with BIM-based methods in the context of shipbuilding.
3. The importance of digital transformation in the maritime sector: The government has encouraged the digitalization of the industrial sector through various programs, but implementation in the maritime sector is still slow. This study is expected to accelerate the implementation of BIM as a form of digital transformation in this sector.
   a. Added value for project management: BIM not only improves efficiency, but also strengthens planning accuracy, documentation quality, and integration between project teams. This research can quantitatively show these benefits in a real context.
   b. Strategic impact on the national shipping industry: If the implementation of BIM proves to be successful in improving project performance, then the results of this study can be a reference for the development of national policies related to digital transformation in the maritime construction sector.

With this background, this study aims to analyze and compare two project management approaches, namely conventional methods and BIM-based methods in the 300-foot deck barge construction project at PT. SKY Batam Island. This study is directed at the aspects of implementation time, estimated cost, and quality of project documentation, which are the main indicators in assessing the performance of a project's management. The findings of this study are expected to make a significant contribution to the ship management capabilities of national shipyard projects and accelerate the process of transformation of the national shipping digital industry in Indonesia.

METHOD

The type of research applied in this study is a type of comparative quantitative research. In the context of this study, a quantitative approach was used to measure and compare the management effectiveness of a 300-foot deck barge construction project between conventional methods and BIM-based methods. Measurement is carried out based on time (project duration) and cost (overall project expenditure) indicators. All data is statistically processed to produce objective and measurable conclusions. The quantitative method is applied because it has the potential to prepare data in the form of numbers that can be analyzed using inferential statistical methods, so that it has the potential to provide an overview of the objectives regarding the significant differences between the two research project management approaches (Creswell, 2014).

This research also has an explanatory nature because this research aims to explain the influence of BIM implementation on project management optimization, namely in terms of the cost duration aspect of the barge construction project. Explanatory research on a quantitative approach aims to test hypotheses and correlations between variables based on numerical data (Neuman, 2014).

And the type of comparison in this study is carried out through:

a. BIM (Building Information Modeling) simulation and modeling in 4D (time) and 5D (cost) formats,
b. Real data from conventional projects documented in the project and then at the same shipyard,
c. Analysis of time and cost efficiency analysis through statistical tests (paired sample t-test or other quantitative methods according to the presumption of data form).

This study acknowledges several methodological limitations that may affect the generalizability and interpretation of results: (1) Generalizability constraints - findings are specific to 300-foot deck barge projects and may not directly apply to different vessel types, scales, or complexity levels, limiting applicability to larger commercial ships or specialized vessels with different construction requirements, (2) Single-site limitation - data collection from one shipyard (PT. SKY Batam) may not represent industry-wide practices or account for variations in organizational culture, resource availability, and technological infrastructure across different Indonesian shipyards, (3) Temporal confounding - the sequential implementation of methods (conventional in 2022, partial BIM in 2023, full BIM in 2024) coincides with potential organizational learning effects and market condition changes that may influence results beyond the technological intervention, (4) Sample size constraints - while statistically adequate for t-test analysis, the sample of 15 projects limits the ability to control for all confounding variables and may not capture the full variability in project outcomes, and (5) Technology maturity bias - BIM implementation benefits may be underestimated due to learning curve effects and potential overestimation due to novelty effects during early adoption phases.

The data collection of this research is intended to obtain reliable and valid information to be able to conduct a comparative analysis between using conventional methods and the use of Building Information Modeling (BIM) in the construction project of a 300-foot deck barge at the PT. SKY Batam Island. Data collection was carried out using a quantitative approach based on field studies and documentation, then analyzed to measure the efficiency of the project time and cost aspects.

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The types of data used in this study include two primary categories, namely primary quantitative data and secondary quantitative data, each of which has the following characteristics:

a. Primary Quantitative Data

The data was collected directly from the real project of the construction of a 300-foot barge deck at PT. The SKY Batam Island shipyard, both through traditional project documents and the results of the use of Building Information Modeling (BIM). Primary data includes:

1) The actual implementation time of the project (the duration of each activity).
2) The actual cost of the project is based on the RAB document and the project's financial statements.
3) Volume of technical work (cutting, installing, welding, etc.).
4) Data from 4D (structured work schedule) and 5D (integrated cost estimation) BIM modeling.
5) This data is numerical data and can be measured objectively, so that it meets the nature of quantitative research, which aims to measure the difference in efficiency between the two project implementation approaches (Sugiyono, 2021).

b. Secondary Quantitative Data

Secondary data is compiled from relevant literature sources, including scientific journals, open books, BIM-based project implementation standards, previous research reports, and shipping industry references. This type of data supports theoretical validity and conceptual frameworks, time and cost efficiency analysis. Some of the secondary data used include:

1) Statistics of the efficiency of the use of BIM in the construction and shipbuilding industry **Eze, E., et al. (2023)**).
2) Standards for duration and productivity in ship fabrication activities.
3) Benchmark data from other projects that have previously implemented BIM or are still using conventional methods.
4) Secondary data is applied as a comparison and reinforcement of arguments in the debate of research results, as well as helping to form conclusions and recommendations based on scientific evidence (Creswell, 2014).

With the existence of the two types of data above, the research is able to present a comprehensive analysis of the efficiency of deck barge construction projects, especially in terms of time and cost based on two different approaches.

The data collection technicians in this study were carried out simultaneously using two basic methods:

a. Actual Project Documentation (Conventional Method)

This data was collected from the documentation of the official implementation of the deck barge project assembled using conventional methods. The data collected includes the project implementation schedule (time schedule), work progress reports, cost budget realization, technical drawings, and project quality control reports. This documentation technique is used to reconstruct real workflows and project achievements based on the approach that has been implemented (Sugiyono, 2021).

b. Application of Building Information Modeling (BIM)
   The implementation of BIM occurs in the same project as the construction of a digital three-dimensional model based on actual technical data (dwg, material volume, sequence of work). The model is built using BIM software (such as Autodesk Revit and Navisworks) to generate the fourth (4D – time) and fifth (5D – cost) dimensions. The implementation of BIM is carried out in the form of real-data, but digital-based, project simulations to measure the efficacy of the project's overall time and cost efficiency (**Eze, E., et al. (2023)**). The results of the process are the estimation of the working duration, the prediction of the cost per component, and the impact detection output that illustrates the effectiveness of the design coordination.

In this study, the data analysis test applied was a quantitative comparative analysis in the form of an independent sample t-test. This test is to find out if there is a significant difference between the two treatments, namely the conventional method and the BIM (Building Information Modeling) method for the two main aspects of the project, namely the project duration (time) and the project cost.

RESULT AND DISCUSSION

Research Results

This study aims to test the difference in project management effectiveness between conventional methods and *Building Information Modeling (BIM)* based on two main variables: project duration (time) and actual cost (Rp). The statistical test used is the Independent Sample t-Test, in accordance with a comparative quantitative approach (Ghozali, 2021; Santoso, 2020).

Calculation of Statistical Test Scores

The calculation of statistical test scores in this study consists of several calculation items as follows:

a. Calculation of Mean Value
   Mean or average is the middle value of a set of data obtained by summing all the values and then dividing by the amount of data. The formulation is as follows:

$$\bar{x} = \frac{x_1 + x_2 + \ldots + x_n}{n}$$

Where:

1) $\bar{x}$ = mean value
2) x_i = i value
3) n = amount of data

b. Calculation of Standard Deviation Values

Standard deviation is a measure of how far the data is spread from the mean (mean). The greater the standard deviation, the more the data spreads from the mean. In contrast, a small standard deviation indicates a more dense and homogeneous data. The formulation is as follows:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Where:

1) s = standard deviation of the sample
2) xi = data value i
3) x¯ = average sample
4) n = amount of data

c. Calculation of t-value

The t-value in a statistical test, specifically in a t-test, is a measure of how much difference the two groups mean compared to the variation (standard deviation) in the data. The formulation is as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where:

1) X¯1,X¯2 : Average of each group
2) s12,s22: Variance of groups 1 and 2
3) n1,n2: Number of samples per group
4) t : Statistical value of t-test

d. Calculation of Degree of Freedom (df) Value

Degrees of freedom (df) is the sum of the free values in a statistical calculation that can still vary after a certain number of parameters are set. The formulation is as follows:

$$df = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1-1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2-1}}$$

Where:

e. Sig. Value Calculation (2-tailed)

   It is a calculation of values when we want to test whether on average two groups differ significantly, without knowing or without caring about the direction of the difference (greater or smaller). The formulation is as follows:

$$\text{Sig. (2-tailed)} = 2 \times P(T > |t|)$$

   Where:

   1) P value < 0.05 : Statistically significant difference
   2) H_0 rejected : Meaning: there is a real difference between the two groups
   3) H_1 accepted: Method A and method B do not come from the same population
   4) P-value < 0.01 : Very significant → very strong evidence
   5) Nialai p ≥ 0.05 : Insignificant → H_0 fail to be rejected

Statistical Test Calculation for Project Duration

a. The calculation of statistical comparison tests on two different methods, namely conventional methods and BIM (partial) methods based on data from the sample in table 4.1 above, is as follows:
   1. Mean value of conventional method: (113 + 100 + 107 + 105 + 102) / 5 = 107.4 days
   2. Mean value of BIM (partial) : (96 + 95 + 94 + 93 + 91) / 5 = 93.8 days
   3. The formulation and calculation of the statistical test output is as follows:

Table 3. Statistical Calculation of Conventional and BIM Project Duration (Partial)

Statistics	**Value**
Conventional Red	107.4
Mean BIM	93.8
Standard Conv Deviation	-4.28
BIM Deviation Standard (passive)	-1.92
t-value	6.48
Df	4.06
Sig. (2-tailed)	**0.0008**

Analysis: Value $p = 0.0008 < \alpha = 0.05$ that there is a significant difference in project duration between conventional methods and BIM (partial). This means that BIM, even though it is partially applied, is statistically proven to be more efficient in project implementation time.

b. The calculation of statistical comparison tests on two different methods, namely conventional methods and BIM (partial) methods based on data from the sample in table 4.1 above, is as follows:
   1. Mean value of conventional method: (113 + 100 + 107 + 105 + 102) / 5 = 107.4 days
   2. Mean value of BIM (full) : (91 + 90 + 89 + 88 + 87) / 5 = **89 days**

3. The formulation and calculation of the statistical test output is as follows:

Table 4. Statistical Calculation of Conventional and BIM Project Duration (Full)

Statistics	Value
Conventional Red	107.4
Mean BIM (penuh)	89
Conventional Standard Deviation	-4.28
BIM Deviation Standard (full)	-1.58
t-value	8.61
df	3.93
Sig. (2-tailed)	**0.0002**

Analysis: The value $p = 0.0002 < \alpha = 0.05$ i.e. there is a significant difference in the duration of the project between the conventional method and BIM (full). This means that the full application of BIM methods has been statistically proven to be better and more efficient in project implementation time.

Statistical Test Calculation for Image Revision

a. The calculation of statistical comparison tests on two different methods, namely the conventional method and the BIM method (partial) based on data from the sample in table 4.2 above, is as follows:
   1. Mean value of conventional method: (24 + 22 + 21 + 20 + 19) / 5 = 21.2
   2. BIM mean value (partial) : (14 + 12 + 11 + 10 + 9) / 5 = 11.2
   3. The formulation and calculation of the statistical test output is as follows:

Table 5. Statistical Calculation of Conventional and BIM Image Revision (Partial)

Statistics	Value
Conventional Red	21.2
Mean BIM (parsial)	11.2
Standard Conv Deviation	1.92
BIM Deviation Standard (passive)	1.92
t-value	5.74
df	2.74
Sig. (2-tailed)	**0.00004**

Analysis: P value = $0.00004 < \alpha = 0.05$ i.e. there is a significant difference in project duration between conventional methods and BIM (partial). This means that BIM, even though it is partially applied, is statistically proven to be more efficient in project implementation time.

b. The calculation of statistical comparison tests on two different methods, namely the conventional method and the BIM method (partial) based on data from the sample in table 4.2 above, is as follows:
   1. Mean value of conventional method: (24 + 22 + 21 + 20 + 19) / 5 = 21.2
   2. BIM mean value (partial) : (6 + 5 + 4 + 3 + 3) / 5 = 4.2

3. The formulation and calculation of the output of the statistical test is as follows:

Table 6. Statistical Calculation of Conventional and BIM Image Revision (Full)

Statistics	Value
Conventional Red	21.2
Mean BIM	4.2
Standard Conv Deviation	1.92
BIM Deviation Standard (passive)	16.358
t-value	5.74
df	7.3
Sig. (2-tailed)	0.00001

Analysis: Value $p = 0.00001 < \alpha = 0.05$ i.e. there is a significant difference in project duration between conventional methods and BIM (partial). This means that BIM, even though it is partially applied, is statistically proven to be more efficient in project implementation time.

Statistical Test Calculation For Project Costs

a. The calculation of statistical comparison tests on two different methods, namely conventional methods and BIM (partial) methods based on data from the sample in table 4.1 above, is as follows:
   1. Mean value of conventional method: (13.8 + 13.5 + 13.4 + 13.25 + 13.1) / 5 = 13.41 M
   2. Mean value of BIM (partial) : (12.9 + 12.8 + 12.75 + 12.65 + 12.6) / 5 = 12.74 M
   3. The formulation and calculation of the statistical test output is as follows:

Table 7. Statistical Calculation of Conventional and BIM Project Costs (Partial)

Statistics	Value
Conventional Red	13.41
Mean BIM (parsial)	12.74
Conventional Standard Deviation	0.265
BIM Standard Deviation (partial)	0.119
t-value	5.15
df	0.42
Sig. (2-tailed)	**0.002**

Analysis: Value $p = 0.0008 < \alpha = 0.05$ that there is a significant difference in project duration between conventional methods and BIM (partial). This means that BIM, even though it is partially applied, is statistically proven to be more efficient in project implementation time.

b. The calculation of statistical comparison tests on two different methods, namely the conventional method and the BIM method (full) based on data from the sample in table 4.1 above is as follows:
   1. Mean value of conventional method: (13.8 + 13.5 + 13.4 + 13.25 + 13.1) / 5 = 13.41 M
   2. Mean value of BIM (full) : (12.45 + 12.45 + 12.40 + 12.35 + 12.3) / 5 = 12.39 M
   3. The formulation and calculation of the statistical test output is as follows:

Table 8. Statistical Calculation of Conventional and BIM Project Costs (Full)

Statistics	Value
Conventional Red	13.41
Mean BIM (penuh)	12.39
Conventional Standard Deviation	0.265
BIM Deviation Standard (full)	0.06
t-value	8.34
Df	0.13
Sig. (2-tailed)	**0.0006**

Analysis: The value $p = 0.0002 < \alpha = 0.05$ i.e. there is a significant difference in the duration of the project between the conventional method and BIM (full). This means that the full application of BIM methods has been statistically proven to be better and more efficient in project implementation time.

Conclusion of Statistical Test Results

From the results of the statistical test through the results of the t-test calculation above, there are the following results

Table 9. Summary of t-test values

Variabel	Nilai Sig.	Statistical Conclusion	Practical Implications
Duration	0.0002 & 0.00004	Signifikan	BIM accelerates project duration
Cost	0.002 & 0.0006	Signifikan	BIM reduces project costs

Interpretation of the results :

The results of the t-test showed a significance value of 0.0002 & 0.00004, which was smaller than the established significance level ($\alpha = 0.05$). This indicates that there is a statistically significant difference between the duration of a conventional project and a project that uses BIM.

In practical terms, BIM projects show duration efficiency with an average time deviation of only +4 days, compared to conventional projects that reach +12 to +23 days. These results reflect that the integration of design and construction information in BIM allows for more coordinated and conflict-free planning and execution.

For the actual cost variable, significance values were obtained of 0.002 & 0.0006, also below the 0.05 threshold. This means that there is a significant cost difference between conventional projects and BIM projects.

In practice, conventional projects experience an average cost deviation of +10% to +18% against RAB, while projects with BIM are only +2% to +5%, This shows that the use of BIM in estimation (5D) can improve the accuracy of budget planning and reduce waste due to rework and design revisions.

The results of this statistical test are in line with the theory of digital-based project management (PMI, 2021) and research findings by Eze et al. (2023) and Mi & Li (2024), which state that BIM contributes significantly to improving the efficiency of construction and shipping projects. With strong statistical evidence, it can be concluded that BIM is not just a visual or modeling approach, but also has a real impact on project performance.

Discussion

The interpretation of the results of the statistical test related to the comparison of project efficiency between conventional methods and Building Information Modeling (BIM)-based methods, was reviewed from the duration of the project and the actual cost. The discussion is also related to project management theory, construction efficiency, and relevant previous research findings. The variables examined based on the framework of thought in Chapter 3 are divided into:

a. Independent variable (X): Working method (Conventional / BIM)
b. Bound variable (Y1): Project duration
c. Bound variable (Y2): Project cost
d. Bound variable (Y3): Technical documentation and coordination

The hypotheses formulated are as follows:

a. H_0: There is no significant difference between the project work methods (conventional and BIM) on project duration, project costs, and technical documentation.
b. H_1: There are significant differences between project methods (conventional and BIM) in terms of project duration, project costs, and technical documentation.

The results of the statistical test in Sub Chapter 4.2 show that the p-value for all variables < 0.05, both in the comparison of Conventional vs Partial BIM and Conventional vs Full BIM, so that H_0 is rejected and H_1 is accepted for all research variables.

Efficiency of Project Execution Duration

The duration of the project showed a significant decrease from an average of 107.4 days (conventional) to 93.8 days (partial BIM) and 89.0 days (full BIM). This decline is in line with the thinking in the theoretical framework in Chapter 2 that 4D BIM allows real-time visualization of schedules and time coordination (Bryde et al., 2020). The t-test yielded a $p < 0.01$, proving a statistically significant difference between conventional and BIM methods. These findings support the results of research by Hamad et al. (2022) and Eze et al. (2023) who stated that the implementation of BIM can accelerate project implementation by up to 20–30% through the integration of scheduling visualization (4D BIM), inter-disciplinary collaboration, and detection of potential conflicts from the beginning. BIM enables more structured work planning, speeds up design validation, and reduces idle time due to miscommunication between divisions.

In the context of the deck barge project at PT. SKY, this efficiency is very important because all the work is done linearly and without a modular block system. Thus, BIM helps minimize disruption by simulating digital work sequences before field execution is carried out.

Project Cost Efficiency

The actual cost average shows the efficiency trend:

a. Conventional: IDR 13.41 Billion
b. Partial BIM: IDR 12.74 Billion

c. Full BIM: IDR 12,39 Billion

With a RAB of Rp 12.50 billion, the BIM method not only keeps costs from exceeding the budget, but in some cases lower than RAB. These findings are in line with the role of 5D BIM which incorporates cost estimation in digital models. The t-test shows $p < 0.01$, so H_1 is accepted for the cost variable. This cost efficiency is in line with the results of a study by Mi & Li (2024) which found that BIM is able to reduce the cost of construction projects by 15–20%, especially with automated cost estimation (5D BIM), digital work volume calculations, and the integration of material information. In barge projects, cost reductions mainly occur due to reduced design revisions, avoidance of rework, and increased coordination between design and production parts.

The image revision and RFI indicators show a very noticeable decline:
Revisions: from an average of 21.2 (conv.) to 11.2 in partial BIM and 4.2 in full BIM.

Statistical tests showed a very significant difference ($p < 0.001$), which showed that the implementation of BIM greatly affected the quality of the project's technical coordination. BIM facilitates centralized collaboration that reduces design conflicts and accelerates technical responses.

Relevance to Theory

This discussion has fully referred to and validated the research design in Chapter 3, namely:

a. The frame of thought is described in the causal relationships X → Y1, Y2, Y3
b. Operational variables are converted into measurable indicators based on time, cost, and revision/RFI
c. The H_0 vs H_1 hypothesis was statistically tested, and the results showed that the entire alternative hypothesis (H_1) was accepted
d. The analysis technique uses the independent two-sample t-test (Welch) as stated in Subchapter 3.7

The results of this study support the project management theory by Kerzner (2017) and the Project Management Institute (PMI, 2021), which states that information integration, schedule control, and accurate cost estimation are the keys to project success. BIM as a digital approach allows for real-time and cross-functional coordination of information, which contributes to the efficiency of project implementation (Eastman et al., 2018).

In shipbuilding practice in Indonesia, this result is relevant because most industries still use conventional methods based on 2D documents. This study shows that digital transformation using BIM is not only relevant for buildings or buildings, but also highly applicable in shipbuilding projects, especially non-mechanical vessels such as barges.

CONCLUSION

Based on the analysis of the 300-foot *deck barge* construction project at PT. *SKY* Batam Island, this study concludes that Building Information Modeling (BIM) significantly optimizes project management compared to conventional methods, by improving time, cost, and documentation efficiency. BIM reduced average project duration to 89 days (full implementation) versus 107.4 days conventionally, with integrated scheduling enabling real-time control of critical paths. Cost efficiency improved as well, with BIM lowering actual costs from IDR 13.41 billion (conventional) to IDR 12.39 billion through reduced rework, enhanced design coordination, and model-based quantity planning. Documentation quality also advanced markedly, shown by fewer drawing revisions and clarification requests, supported by cross-functional integration and transparency. These findings reinforce BIM's role as a critical digital strategy facilitating the transformation of Indonesian shipyards toward data-driven, collaborative maritime industry practices. Future research could explore the long-term impacts of BIM implementation across varied shipbuilding scales and environments, as well as integration with emerging technologies like AI and IoT to further enhance project management efficiencies.

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