Analysis of Benefit Cost Ratio in the Utilization of BIM in the Construction Project of the Mobile Brigade Corps Building (MAKO Brimob) and the State Police School (SPN) of North Sulawesi Regional Police

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Abstract

PT Buana Enjiniring Konsultan is one of the engineering consulting firms in Indonesia. In addition to being active in the engineering field, PT Buana Enjiniring Konsultan has also ventured into digital engineering by providing Building Information Modeling (BIM) services. As a subsidiary of PT Brantas Abipraya, PT Buana Enjiniring Konsultan is committed to ensuring that the BIM products provided are of high quality and meet construction industry standards. By utilizing BIM, clash detection can be carried out effectively and efficiently, thereby preventing additional costs due to on-site corrections. The aim of this research is to analyze the Cost Benefit Ratio achieved by using BIM in the construction of the MAKO BRIMOB and SPN Polda buildings in North Sulawesi. The research employs a quantitative method. The results indicate that the Benefit Cost Ratio for the MAKO Brimob and SPN Polda North Sulawesi project is 5.33, meaning that the benefits of the project outweigh the costs incurred. Therefore, the use of BIM can lead to greater cost efficiency.

Keywords

Engineering, building information modeling (BIM), benefit cost ratio, clash detection

INTRODUCTION

In the era of Industry 4.0, information technology is rapidly advancing, including in the construction sector. This undoubtedly impacts the effectiveness and efficiency of work outcomes in construction projects. Building Information Modeling (BIM) has become a significant milestone in the digital transformation of the construction industry. BIM is a method that starts with creating intelligent 3D models and supports document management, coordination, and simulation throughout all phases of the project life cycle, including planning, design, construction, operation, and maintenance [1]. BIM provides a detailed and accurate representation of construction projects in a virtual space.

Although some contracting companies in Indonesia have begun to implement Building Information Modeling (BIM), many others have not yet adopted it. As a result, the government has issued regulations governing the use of BIM in construction service companies, including Law No. 2 of 2017 on Construction Services. Article 5, Paragraph (5) states that "The Central Government has the authority to develop standards for construction materials and equipment as well as innovations in construction technology.[2]"

BIM not only provides three-dimensional models of buildings but also stores valuable information about properties and material specifications. This enables construction professionals to integrate data from various disciplines and project stages, supporting everything from project design planning, scheduling, budgeting, to other information. Additionally, BIM facilitates stakeholders (consultants, facility managers, civil engineers, owners) to exchange data, communicate, and collaborate in real-time [3]. In addition to improving data management and maintaining coordination and communication, another top benefit of BIM for stakeholders is the increase in productivity, time efficiency, cost savings, and clash detection [4].

In Indonesia, many construction companies still rely on traditional methods, such as using AutoCAD for design drawings, SAP for structural analysis, Microsoft Excel for volume and cost calculations, and Microsoft Project for scheduling. Building Information Modeling (BIM) transforms the planning paradigm by introducing an integrated process for developing design and construction documentation. With BIM, various construction documents, such as drawings, procurement details, and specifications, can be easily interconnected and managed efficiently [5]. An effective BIM application must support the entire workflow throughout the building project life cycle. BIM software offers a variety of features such as visualization, documentation, clash detection, and cross-disciplinary integration and collaboration. Additionally, this software supports interoperability through standards

like IFC and interface communication. Autodesk Revit is an example of software that implements the BIM system. With Autodesk Revit, users can design and plan construction projects from architectural, structural, to MEP aspects in 3D, 4D, and 5D formats [6].

To assess the effectiveness and efficiency of construction project outcomes, one method used is the Benefit Cost Ratio (BCR) analysis. BCR is the ratio of total benefits, converted to present value, divided by the total costs, also converted to present value. This ratio indicates the project's feasibility; a higher BCR reflects better economic viability. BCR is calculated by applying a discount rate, and a project is considered economically viable if BCR > 1 [7].

PT Buana Enjiniring Konsultan is an engineering consultancy firm that provides Feasibility Study (FS) and Detail Engineering Design (DED) services. Established in 2015, the company underwent significant transformation in 2021 by expanding its business scope into digital engineering, offering Building Information Modeling (BIM) and Virtual Design Construction (VDC) services. One project that utilizes BIM is the construction of the Police Academy (SPN) & MAKO Brimob in North Sulawesi. This project is scheduled to be completed within 300 days, from August 11, 2023, to June 10, 2024, with a BIM contract value of Rp 579,975,000. The design of the Police Academy (SPN) & MAKO Brimob building involves various professionals, such as architects, structural engineers, and MEP engineers. Once the design is complete, it is reviewed using BIM to identify clash detection.

Clash detection is one of several quality checks performed by designers before their models are submitted for the next phase. These clashes can be considered errors or deficiencies that need to be resolved, often requiring discussions among designers, modelers, and contractors from various disciplines [8]. In conventional construction project processes, clash detection is typically identified during the construction phase. This can lead to cost overruns and delays. With BIM, clashes can be detected through 3D product models. The integration of BIM methods with 3D modeling is effective for energy efficiency, better design, cost reduction, and structural isolation [9]. Clash detection identifies and analyzes conflicts or clashes between various elements and systems within a 3D model. If these issues are not addressed early on, they can lead to problems during the construction phase. The presence of clash detection in BIM helps identify and resolve conflicts before the construction phase, thereby avoiding costly repair and modification expenses.

PT Brantas Abipraya (Persero), the parent company of PT Buana Enjiniring Konsultan, has received an award for the construction of the Police Academy and MAKO Brimob Project in North Sulawesi. This project has passed the selection process for the Autodesk ASEAN Innovation Awards 2024 and has been recognized as a Top Entry in Indonesia, representing the country in the Cloud Advocate of the Year Award category. This success is attributed to the support of all project stakeholders, including Abipraya, the Ministry of Public Works and Housing (PUPR), and the consulting team, in the implementation of BIM technology, particularly the use of Common Data Environment (CDE). Abipraya was chosen as the best among several participants from Indonesia.

Rizqy et al. (2021) [5] conducted a study to evaluate the advantages and disadvantages of BIM, considering that this technology is relatively new. The research employed a questionnaire and interviews with experienced drafters and engineers in the construction field who have implemented BIM. In the case study of the Jakarta-Cikampek II Selatan Toll Road (Package 3) planning, a comparison was made between cost and time efficiency using conventional methods versus BIM. The results indicated that the implementation of BIM could accelerate the work process by up to 43.82%, although the costs incurred were higher compared to conventional methods due to the substantial initial investment required for software licenses.

Ulinnuha et al. (2024) [6] conducted a comparative analysis study on cost estimation between the use of Autodesk Revit and conventional methods, providing insights into the efficiency and effectiveness of using BIM software for construction project cost estimation. The research focused on the structural work of the Satpol PP Bantul office construction project. The methodology employed included data collection, 3D BIM modeling, cost estimation calculations based on the volume produced using unit cost analysis, and a comparative analysis of cost estimation between BIM software and conventional methods. The study found that the cost estimation for structural work using Revit amounted to Rp 862,330,518.59, with a difference of Rp 53,420,195.31. This indicates that the use of 3D BIM resulted in calculations that were 5.83% cheaper compared to conventional construction cost estimation methods.

Berlian P. et al. (2016) [10] conducted a study to evaluate the benefits of the BIM method compared to conventional methods. In Indonesia, many construction practitioners have not adopted or fully understood the concept of BIM. This research utilized questionnaires, interviews, and case studies to assess the understanding and performance of BIM. In the case study of planning a 20-story building, a comparison was made between the efficiency of conventional methods and BIM in terms of time, human resources (HR), and project planning costs. The results indicated that the implementation of BIM could accelerate project planning time by approximately 50%, reduce HR requirements by 26.66%, and save personnel costs by 52.25% compared to conventional methods.

Shin et al. (2018) [11] conducted a study on the use of BIM and its advantages in construction. The scope of the research focused on a railway construction site in South Korea, which included multiple railway lines, stations, telecommunication facilities, infrastructure facilities, railway structures, and more. At this site, the authors identified 12 preventable errors across 7 projects that could have been avoided if BIM had been utilized prior to construction. The total upfront cost required to provide BIM for the seven projects was $116,348. On the other hand, the total cost needed to rectify the errors in the seven projects amounted to $166,486. This demonstrates the benefits of using BIM, as project-related errors can be more easily addressed with its implementation. Therefore, the benefit-cost ratio was estimated at 1.32 for a one-month delay and 1.36 for a three-month delay.

Hamid and Abdelhaleem (2021) [12] conducted research showing that 5D BIM has significant potential to improve construction cost estimation by reducing the disparity between planned and actual project costs. This underscores the usefulness of 5D BIM technology in project cost calculations. 5D BIM generates accurate Bills of Quantities through specialized techniques to maintain consistency in cost information. The study found that the variance between planned and actual costs decreased from 12% to 5% when 5D BIM was used instead of traditional methods. Therefore, accurate cost estimation and clash detection are valuable outcomes of 5D BIM.

Rosmyanto et al. (2022) [13] conducted a study on the costs of rework in construction, using design evaluation data with Building Information Modeling (BIM) systems for the Politeknik Astra Campus Building project. The methods applied in this research included observation and analysis, utilizing Autodesk Revit software for the analysis. The results of the study indicated the presence of potential rework risks, specifically in reinforced concrete work amounting to 50.843 m³, 48 units for window work, as well as wall areas of 112.22 m² and ceilings of 52.38 m². The research also found a construction cost savings of 0.91% of the total project cost, attributed to early detection of rework risks, thus preventing the need for such work on-site. Furthermore, the findings suggest that the implementation of BIM, particularly through clash detection reports, positively impacts the volume and cost of project work.

Soebandono, et al. (2022) [14] conducted 3D modeling for the complete structure of a building project using Tekla Structures Student License software. This research continued with budget planning using the Quantity Takeoff (QTO) method from Tekla Structures.The results showed that for the superstructure, there were discrepancies of 0.28% for concrete, 1.1% for steel, and 0.22% for formwork, indicating efficiency in calculations using BIM methods. Meanwhile, for the roof structure, the detected discrepancies were 3.39% for rafters, 0.4% for purlins, 1.23% for beams, and 0.42% for battens, where the calculations for battens demonstrated better efficiency with BIM methods. In terms of cost calculations, the discrepancies recorded for the substructure were 0.48% (Rp 1,452,861), for the superstructure 0.58% (Rp 14,078,298), and for the roof structure 1.4% (Rp 6,795,712). All these discrepancies indicate that the use of BIM methods in volume takeoff is more cost-efficient.

RESEARCH SIGNIFICANCE

The aim of this research is to demonstrate that using BIM can identify potential issues earlier in the design phase, reducing sudden changes and delays during construction. Using the Benefit-Cost Ratio (BCR) method will lead to savings (efficiency) in time and costs for the construction of the Mobile Brigade Corps (MAKO Brimob) Building and the State Police School (SPN) Polda North Sulawesi.

METHODOLOGY

Based on Figures 1, 2, and 3, the location of the MAKO Brimob Building and the Police School (SPN) project of North Sulawesi Police is in Kalasey 2 Village, Mandolang District, Minahasa Regency, North Sulawesi. This project was carried out over 322 days, from December 2019 to July 2021, with a BIM contract value of IDR 579,975,000.

Figure 1 Location of the MAKO BRIMOB and SPN Polda project in North Sulawesi.

Figure 2 3D View of the MAKO BRIMOB and SPN Polda Project Location

Figure 3 Location of the Mako Brimob Building in Kalasey 2 Village, Mandolang District, Minahasa Regency.

A. COLLECTION OF TECHNIQUE DATA

This research aims to identify the Cost Benefit Ratio (BCR) of using BIM at PT Buana Enjiniring Konsultan. The research method employed is quantitative. The methodology includes data collection, 3D BIM modeling, cost estimation calculations based on the produced volume using cost-benefit ratio analysis, and a comparative analysis of cost estimates between BIM software and conventional methods. Data was obtained from the PPK PUPR team for the MAKO Brimob & Polri Building project in North Sulawesi, PT Brantas Abipraya (Persero), specifically from the Division 1 Project Team, and PT Buana Enjiniring Konsultan.

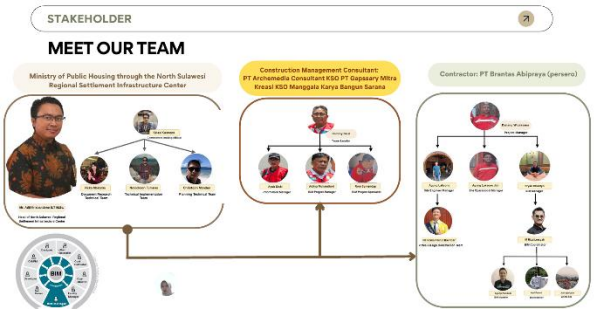


Figure 4 Stakeholders in the MAKO Brimob & Polri Building Project in North Sulawesi

RESULTS AND DISCUSSION

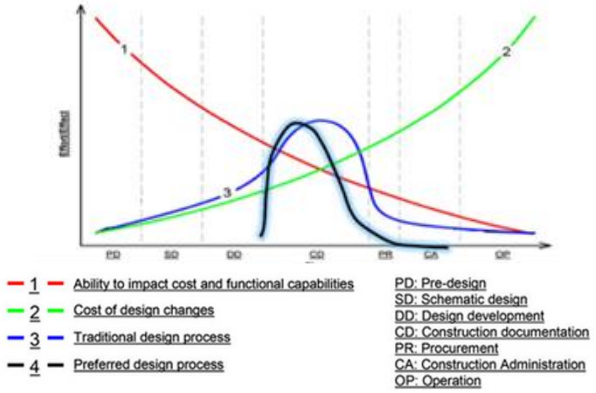


Figure 5 Kurva Kerja BIM PT BEK

BIM serves as a collaborative and innovative tool that can enhance the quality, efficiency, and sustainability of projects by maximizing the use of a Common Data Environment (CDE). The primary objective of the CDE is to promote ongoing collaboration by acting as a data management system while also serving as an accessible platform for smooth data exchange [15]. To achieve this goal, all stakeholders must adopt policies and techniques to ensure data quality within the system.

Based on Figure 5, the BIM process at PT Buana Enjiniring Konsultan seems to minimize effort, rework, and costs toward the end of the project by reducing them at the outset. Greater effort in the early stages of the project will lead to more significant benefits later on.

Based on Figure 6, most projects in Indonesia require BIM, but it has not yet become a standard part of project management requirements. A characteristic is that the Common Data Environment (CDE) is not utilized, or it is only used as a storage space like Google Drive. According to the graph below, BIM has not been optimally developed in the early stages of the project.

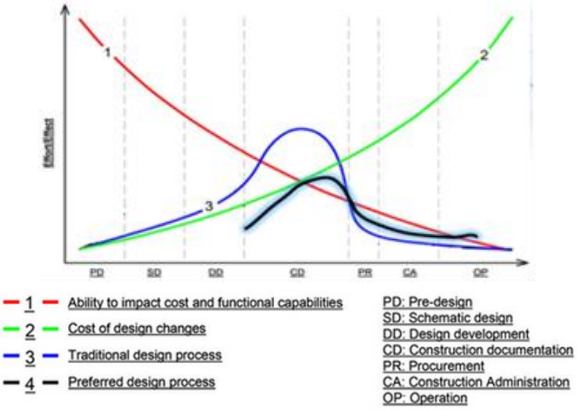


Figure 6 BIM Work Curve for Most Companies in Indonesia.

MORE EFFICIENT COMMUNICATION

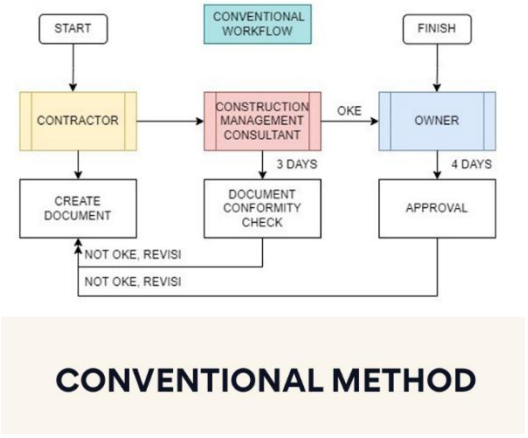


Figure 7 Communication with Conventional Methods

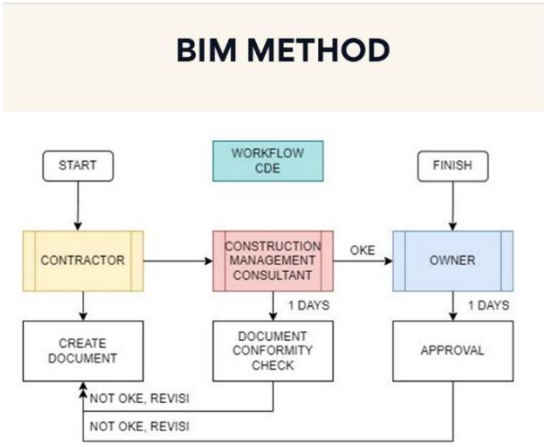


Figure 8 Communication with BIM Methods

COMPARISON OF COMMUNICATION EFFICIENCY: CONVENTIONAL METHODS VS. COMMON DATA ENVIRONMENT METHODS

Based on Figure 9, the Common Data Environment (CDE) is a collaborative platform that integrates various project data through cloud technology. By leveraging the CDE, all parties involved in the project can collaborate and manage project issues effectively in a digital format. The CDE

provides opportunities to enhance cooperation and efficiency in the construction sector. One example of a CDE platform is BIM 360 from Autodesk, which is used for communication and coordination among construction professionals during the design review process.

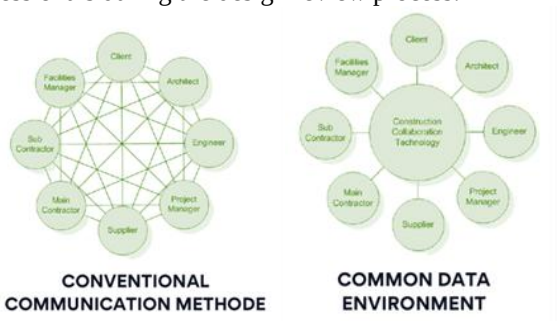


Figure 9: Comparison of Work Differences Using CDE vs. Conventional Methods

DIGITAL ASSET MANAGEMENT

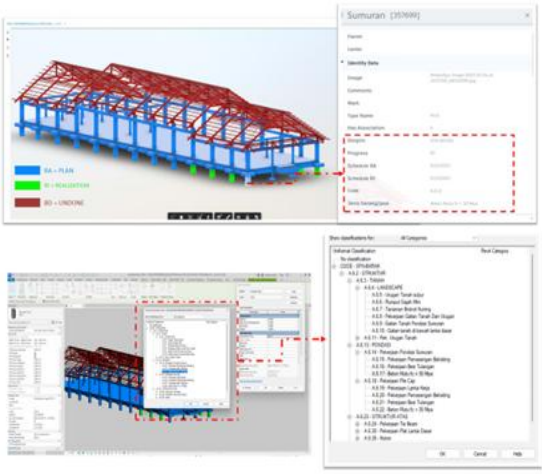


Figure 10 Digital Asset Registration

Based on Figure 10, Asset Information Modeling (AIM) is a valuable tool for efficiently and effectively managing physical assets throughout their lifecycle. This model provides a holistic data-driven approach to asset management, which can result in cost savings, better decision-making, and overall improved asset performance. The benefits of implementing AIM in this project as a digital investment include: Detailed information about each building component in the project will be recorded. AIM is designed to store all information during pre-construction, updated according to changes during construction, and used for asset management accounting during operations and maintenance.

CONSTRUCTION VISUALIZATION

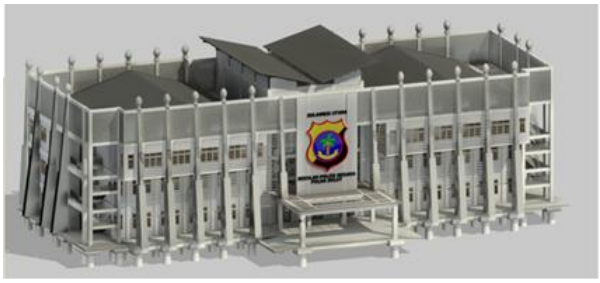


Figure 11: Design of the Mako Brimob Building in Manado

Based on Figure 11, construction visualization in digital construction allows for a better understanding of the project design, construction process, and final outcomes

Figure 12: Design of the Mako Brimob Building in Manado

Based on Figure 12, the pre-construction modeling process produces LOD 300 and LOD 400, which will then be developed into LOD 500 during the construction phase.

CLASH DETECTION

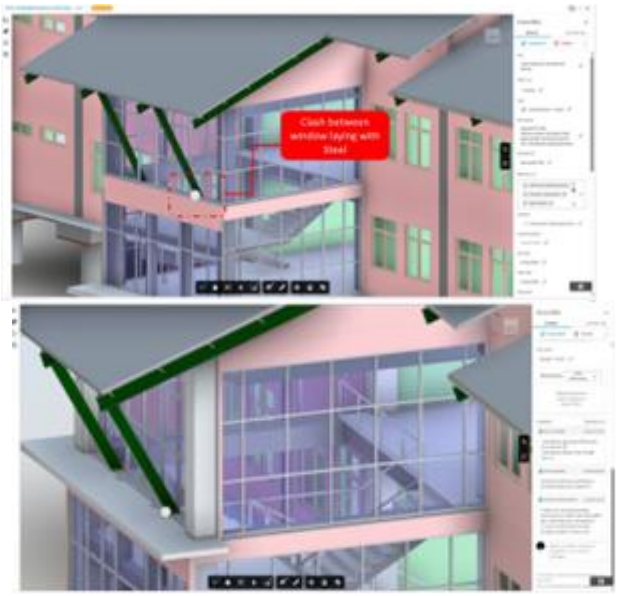
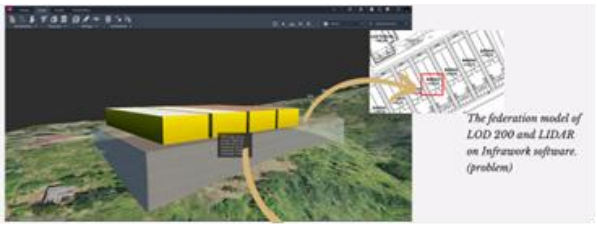


Figure 13 Clash Detection in the Design of the Mako Brimob Manado Building

Based on Figure 13, the issues are caused by design planning, where Architecture and Structure do not overlap correctly, leading to design inconsistencies. Solutions to design inconsistencies are discussed by stakeholders on the CDE platform. The construction management consultants will provide recommended solutions for approval by the project owner.



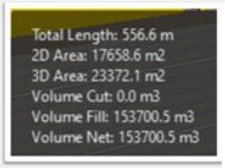


Figure 14 Federation model LOD 200 and LIDAR in Infraworks software. (issues)

Based on Figure 14, the results from the federation model in Infraworks software indicate that the LOD 200 building model shows the planned building elevation at +70.75 m in the Barrack building, while the LIDAR results at the project site show existing ground conditions at +64.00 m in the Barrack building. The planning drawings indicate earthwork with a volume of 153,700.5 m³. In this case, the two sets of data are not well synchronized and do not match the ground level data provided by the LIDAR.

Figure 15 Detail of the issue as seen from the 2D Satellite Image

Topography **:** The geographical condition of the SPN building is located in a hilly area. According to the planning documents, the volume of earthworks required will be substantial.

Layout **:** Reconfiguring the building layout must maintain the functional interconnection between the buildings, as these facilities are closely interconnected.

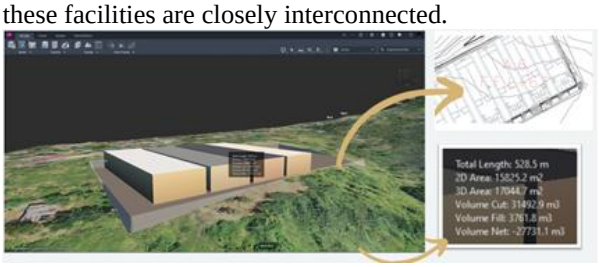


Figure 16 Federation model LOD 200 and LIDAR used in Infraworks software. (solution)

Based on Figure 16, the BIM modeling has been simulated with a high volume of 31,492.9 m³, and earthworks with a volume of 3,761.8 m³. If this issue is not addressed early on, problems will arise during the construction phase. This issue also impacts the cost of work. We identified an overspending in the cut & fill work items.

Table 1 DED Work and Design Review

DETAIL ENGINEERING DESIGN DRAWING

ITEM	VOL (m3)	HARSAT	TOTAL
CUT	0	26,978.00	-
FILL	153,700.50	26,306.00	4,043,245,353.00
		TOTAL	4,043,245,353.00

REVIEW DESIGN

ITEM	VOL (m3)	HARSAT	TOTAL
CUT	31492.9	26,978.00	849,615,456.20
FILL	3,761.80	26,306.00	98,957,910.80
		TOTAL	948,573,367.00

Based on Table 1, the risk of cost estimation for potential landfilling is around Rp. 4,043,245,353. In contrast, the design review using LIDAR only incurs a cost of Rp. 948,573,367. This results in a savings of Rp. 3,094,671,986. With BIM, the benefits include early problem detection, which helps reduce changes and corrections in the field.

$$BCR = \frac{Benefit\ Cost}{Total\ Cost} = \frac{3.094.671.986}{579.975.000} = 5{,}33$$

From the calculations, the BCR value obtained is 5.33. A BCR value greater than 1 indicates that the benefits or advantages derived from the MAKO Brimob and SPN Polda Sulawesi Utara building project are significantly greater than the costs incurred.

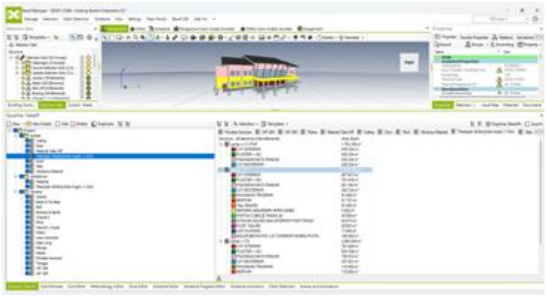


Figure 17 Cost Saving

Quantity Measurement : BIM can be integrated with cost estimation software to provide accurate cost projections. By linking cost data to the BIM model, reports and cost estimates can be generated.

Quantities : BIM software can automatically calculate material and component quantities, facilitating accurate quantity measurements for cost estimation.

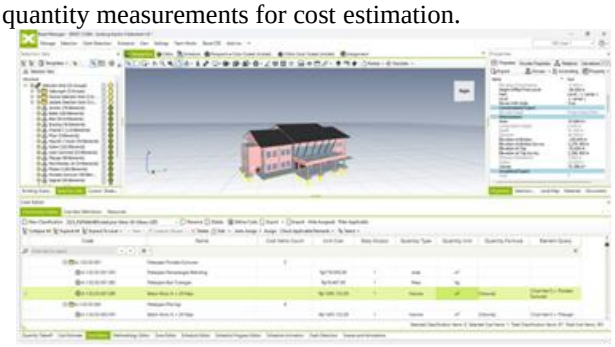


Figure 18 Time Saving

Virtual Construction Sequencing

BIM can visualize the sequence and stages of construction.

Schedule Visualization

In this project, the implementation of BIM facilitates communication and understanding of the project schedule.

CONCLUSIONS

Based on the Cost Benefit Ratio (BCR) data analysis for the construction of the Mobile Brigade Corps Building (MAKO Brimob) and Police School (SPN) in North Sulawesi, this research demonstrates that the use of BIM allows for clash detection identification before construction begins, enabling issues to be resolved early without additional costs. By collecting cost and benefit data from the project, followed by BCR analysis to measure the generated cost-benefit ratio, the results indicate that the use of BIM yields a benefit-cost ratio of 5.33. This shows that the implementation of BIM at the MAKO Brimob Project

Development stage provides a value 5.33 times greater in terms of effectiveness and efficiency compared to the costs incurred for BIM services.

It is recommended that construction projects utilize BIM from the planning stage to achieve improvements in effectiveness and efficiency. Future research could focus on calculating the BCR for the use of BIM in construction projects beyond building construction, such as infrastructure projects like roads, water facilities, and others.

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