Building Information Modeling-based Cost Estimation

The Case Study of the Guntung Payung Banjarbaru Community Health Center Building Project

Candra Yuliana
Professional Engineer Education Department, University of Lambung Mangkurat, Indonesia
candrayuliana@ulm.ac.id (corresponding author)

Ibnu Fathonah
Civil Engineering Department, University of Lambung Mangkurat, Indonesia
ibnuftnh@gmail.com

Retna Hapsari Kartadipura
Professional Engineer Education Department, University of Lambung Mangkurat, Indonesia
arikartadipura@ulm.ac.id

Endah Widiastuti
Civil Engineering Department, University of Lambung Mangkurat, Indonesia
endah.widiastuti@ulm.ac.id

Received: 9 December 2024 | Revised: 2 January 2025 | Accepted: 11 January 2025

 DOI: https://doi.org/10.48084/etasr.9890

ABSTRACT

This study conducts a comparative analysis between a Business Information Modeling (BIM)-based and traditional cost estimation methods on the building structure of the Guntung Payung Banjabaru Health Center, Banjabaru City. The Tekla Structures (TS) software is utilized to carry out structural work calculations, including concrete, steel, and iron work, as well as the AHSP/HSPK working drawings from 2021. The BIM analysis results regarding the calculation time and cost differences were compared with the calculation results obtained with Microsoft Excel and AutoCAD. The two methods' findings demonstrate that the cost difference is 12% for the concrete work and 13% for the iron/rebar work. It can be concluded that the BIM cost estimation method is more efficient, because its processing time is shorter and the calculation results are closer to the project needs compared to the conventional method.

Keywords-BIM; building structure; cost estimation; tekla structures; concrete and steel work

I. INTRODUCTION

Construction technology is being rapidly developed, making it easier to increase the construction project design effectiveness. In project planning, various software programs are used to improve project efficiency. However, they face several challenges, such as lacking an offline database, resulting in data discrepancy. To tackle this issue, Building Information Modeling (BIM) was created as an outcome of the technological innovation in the construction industry [1]. The applications used for project planning before the BIM emergence were time-consuming because they could not be integrated with each other, influencing the time, cost, and human resources required for project planning [2].

BIM is a 3D model-based process of generating and managing data, such as geometry, spatial relationships, quantities, component properties, etc. During the life cycle of a building [3, 4], one part of the planning is the calculation of the construction costs, which is carried out by planners who play an important role in executing tenders. The estimated costs calculated by the planners can be referred to as the Engineer Estimate (EE) [5]. Planners use a Bill of Quantity (BQ) as a basis for checking the project progress, which requires careful implementation to be as detailed as possible when applied in the field. The calculation of the average work volume is attempted manually with reference to the engineering design details that have been determined so that the calculation results can approach the actual conditions in the field [6]. Nevertheless, in classical calculations, there are times when things on the ground do not work, which may be disproportionate to the work amount. This kind of situation can affect the total expenditure estimate, whether it impacts the determination of the bid price itself or the bid price of the contractor. Such an inaccuracy can lead to a swelling of expenses if the volume calculation is very large and a work quality reduction if the volume calculation is very small [7].

A. Building Information Modeling

BIM is a digital representation of the physical and functional characteristics of a facility [8]. It serves as a shared knowledge resource for the facility data, providing a reliable basis for decision-making throughout its life cycle, that is, from inception onwards. The fundamental premise of this model is the collaboration among various stakeholders during different phases of the facility life cycle, allowing them to enter, extract, update, or modify data in the modeling process to support and reflect their positions. Models are shared digital representations based on open standards for interoperability. The model can consist of a set of interconnected files rather than being just a single entity [9-12]. BIM integrates as-built data with design data for project control, enhancing the quality, timeliness, and cost performance of off-site construction projects. Studies on as-built information focus on evaluating the structural members and ensuring quality control. Risk management and value management, as integrative models with BIM, are employed to identify risks and assess their impact on costs or the cost estimation process [13].

Rooted in the BIM technology, lean production enables construction operations to eliminate waste (both time and resource), ensure order in production, and properly organize the resources for each stage. Additionally, it certifies that the final product maximizes the investment benefits and meets customer needs, particularly by reducing building waste. In Vietnam, the lean philosophy remains a relatively new concept that has not been fully developed. However, efforts have been made to streamline the construction process during projects. Various aspects of the Vietnamese construction industry require access and development due to the challenges faced by Collaborative Design Environments (CDEs) in managing BIM, a shortage of human resources, and disorganized administration [13].

B. Budget Plan, Quantity Take-Off, and Bill of Quantity

To determine the required budget, a Budget Plan (BP) can be created, which constitutes the BP needed for carrying out activities, the volume required for equipment, materials, or labor [14]. Additionally, the BP is used in the proposal document as a requirement for participating in tenders. BP helps calculate and accurately identify how much budget is needed to construct a building according to the owner's request. Without a BP, it is very likely that there will be an increase in expenditures due to the purchase of building materials that do not match the work volume, uncontrolled worker wages, inappropriate equipment procurement, and various other negative consequences.

Quantity Take-Off (QTO) is a part of the process of determining the project budgets. It is generally performed manually, which may lead to some inaccuracies and errors. However, there are BIM programs that include various tools necessary for creating QTOs [15]. The QTO results are then compared, and the achieved savings are calculated [16, 17]. The focus of this work is to assess the reliability of the QTO applied through the BIM methods. The BQ is a list of estimated quantities that can be measured, but may not always be entirely accurate due to unknown conditions that may arise during project execution. The purpose of organizing the BQ is to assist contractors in producing accurate tenders effectively and to aid post-contract administration in carrying out tasks efficiently and within budget [10]. It is essential to note that design quality plays a crucial role in achieving budget savings by enabling the creation of an accurate BQ and by utilizing planners to develop good calculations regarding the work methods.

There are three main factors that contribute to QTO accuracy [18]. Initially, when the QTO is not carried out by BIM, the data are typically transferred between the BIM and cost estimation software utilizing open-standard Industry Foundation Classes (IFCs), which are able to convey the geometric and semantic information about the building elements. Although the IFC-based BIM model offers many uses, it may not include all the information required to perform an accurate QTO, while data loss may occur during the IFC conversion. Nevertheless, the data contained in BIM models might not be enough for QTO. Secondly, detailed building features cannot be incorporated in the BIM when the latter is designed, while these features' quantity may either be too large or too small. Thirdly, the BIM model quality, particularly concerning the geometry of the 3D elements and associated parameters, has a significant impact on the QTO calculated from it. For example, the steel volume and density or the steel elements' length and the nominal weight value of the steel section can be used to determine the amount of the steel weight.

II. METHODOLOGY

The stages of the research method [19] are: (a) collecting secondary data, such as project design images and budget documents, from planners; (b) designing a 3D model based on the project design images; (c) analyzing the QTO from the 3D modeling after having created an organizer; (d) analyzing cost comparisons for both methods (BIM and manual/conventional); (e) determining the advantages and disadvantages in cost estimation using BIM (TS) and manual (conventional).

III. RESULTS AND DISCUSSION

The process of creating a 3D model using TS involves several stages, starting with importing the CAD file of the structural layout into the TS as a basis for establishing the grid and depicting each 3D part. The grid is set according to the building axes: width (X), length (Y), and elevation (Z), which helps determine the structural components to be created. The data components are organized in the properties tab according to the plan drawings. The properties for the concrete materials are configured by modifying the identity, dimensions, material, class, location, cast unit, and thickness of the concrete cover. For the rebar section, the properties are adjusted by changing the identity, type, size, bend, and quantity of reinforcement. Lines are then drawn between the points connected by the grid according to the design drawings to produce images of each component.

This project utilizes piles measuring 20 × 20 cm and 6 m long for each pile with a concrete quality fc=20 MPa. The reinforcement for the pile cap types PC1 and PC2 uses the same diameter and spacing, specifically D16 – 200 for transverse and D16 – 200 for longitudinal reinforcement, with stirrups made of Ø10. For pedestal columns measuring 30 × 30 cm with concrete with fc=20 MPa, while each column is 1.5 m long per point. The beam modeling is performed according to elevations that follow the top of the pile cap. Beam S1 has dimensions of 25 × 35 cm, while S2 has dimensions of 15 × 20 cm. There are two types of columns to be modeled: K1 and K2. On the first floor, there is only one column type, K1 with dimensions of 30 × 30 cm, modeled from elevation +0.000 mm to +4.000 mm, resulting in a total height of 4.0 m. On the second floor, there is equivalently one column type, K2 with dimensions of 25 × 25 cm, modeled from elevation +4.000 mm to +8.000 mm, also resulting in a height of 4 m. On the third floor, there is again only one column type, K2 with dimensions of 25 × 25 cm, modeled from elevation +8.000 mm to +12.000 mm, maintaining a height of 4 m. This project includes four different types of beams: B1A, B2, B3, and B4, each with distinct dimensions, shapes, and reinforcements.

The Guntung Payung Health Center project consists of three floors and one roof deck. All slabs are 12 cm thick with fc=20 MPa concrete. The elevation for the first-floor slab is set at +4.000 mm, for the second-floor slab at +8.000 mm, and for the roof deck slab at +12.000 mm. During modeling, the first step is to input the slab layout. This option is used to model the floor slab reinforcement similarly to other structures while adjusting its properties. However, there are slight differences due to a two-way reinforcement installation. The utilized reinforcement is D10 with a spacing of 150 mm. The floor reinforcement is divided into two parts: top and bottom reinforcement during installation in both X and Y directions. The stair modeling consists of only one model since the stairs from the first floor to the second and from the second to the third are identical. For modeling the stair treads, there are two methods: using existing models from the Application and Component approach or importing cross-sectional shapes and dimensions that align with the design plans. The Application and Component method is more practical and easier to understand, thus speeding up the design processes. Each structural modeling component is depicted in Figures 1-8.

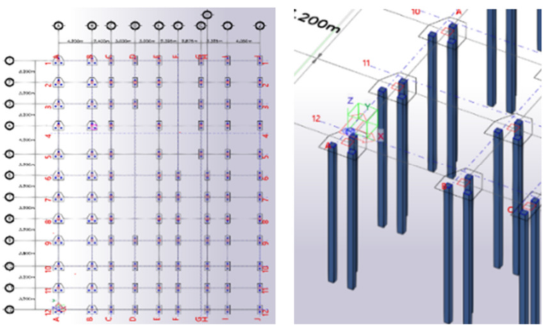

Fig. 1. Pile modeling.

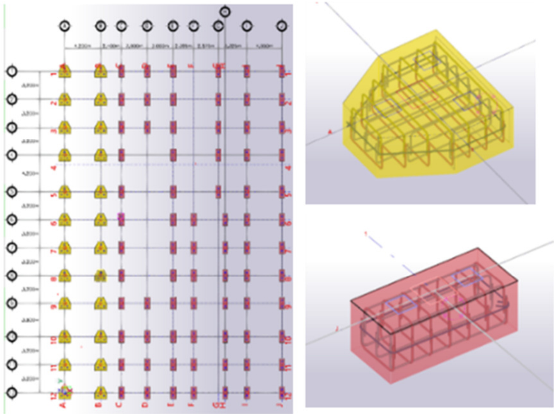

Fig. 2. Pile cap modeling.

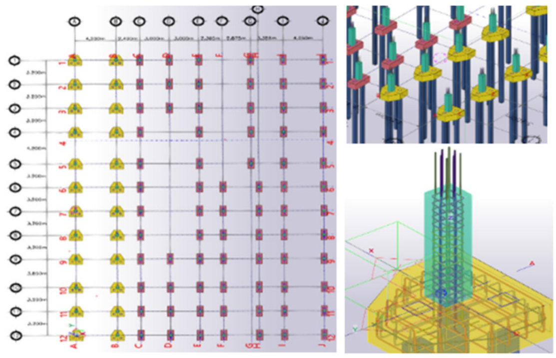

Fig. 3. Pedestal column modeling.

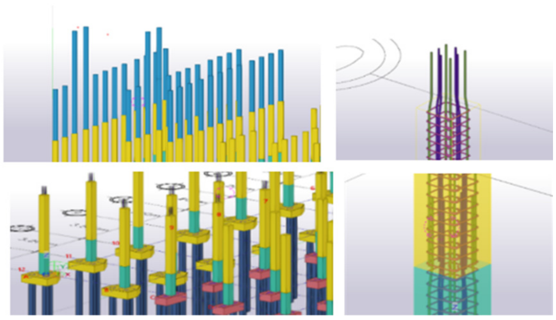

Fig. 4. K1 and K2 column modeling.

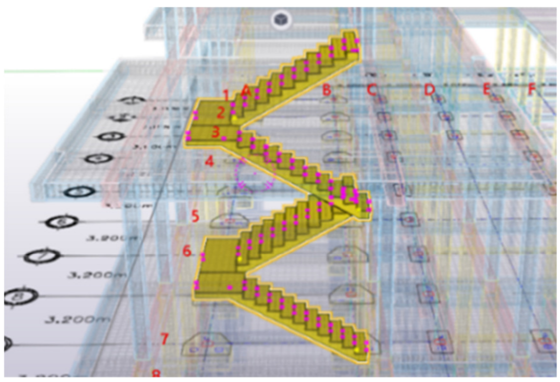

Fig. 5. Stair modeling.

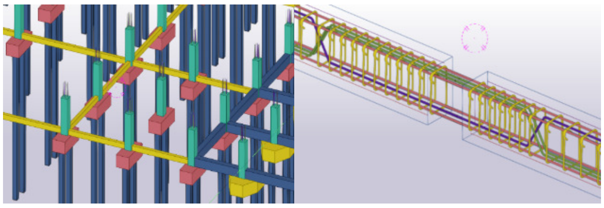

Fig. 6. Sloop modeling.

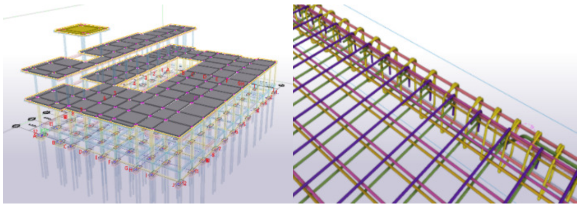

Fig. 7. Beam modeling.

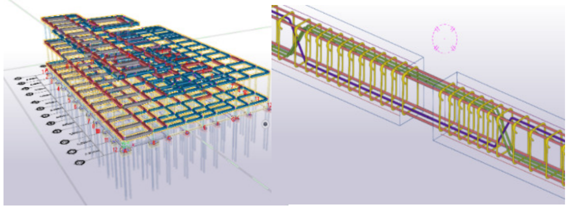

Fig. 8. Floor modeling.

The results obtained from the analysis and discussion of studies on volume calculations and cost budgets [20], using the BIM method and traditional methods are shown in Tables I and II. Based on the results of the main structural work weight, outlined in Table II, there is a significant total price difference, exhibiting an increase of 5.69% (IDR 109,973,460) when using the BIM approach compared to the conventional method.

TABLE I. RECAPITULATION OF WORK PRICES BASED ON BUILDING STRUCTURE FLOOR

No	**Work Item**	**Total Cost (incl. VAT)**		**Difference**		**Weight (%)**
		Conventional (Rp)	**BIM TS (Rp)**	**Increase (Rp)**	**Decrease (Rp)**	
A	**1st Floor Building Structure**					
	Piling Work	445,280,000	445,280,000	-	-	0.00
	Concrete fc=20 MPa	232,408,936	255,106,512	22,697,577	-	9.77
	Iron work	401,033,218	435,215,627	34,182,409	-	8.52
B	**2nd Floor Building Structure**					
	Concrete fc=20 MPa	239,395,296	216,599,371	-	22,795,925	-9.52
	Iron work	371,131,471	449,541,689	78,410,217	-	21.13
C	**3rd Floor Building Structure**					
	Concrete fc=20 MPa	83,296,610	58,691,727	-	24,604,883	-29.54
	Iron work	122,224,635	149,714,742	27,490,108	-	22.49
D	**Stair Roof Building Structure**					
	Concrete fc=20 MPa	19,579,801	9,861,113	-	9,718,687	-49.64
	Iron work	19,328,693	23,641,339	4,312,646	-	22.31

TABLE II. RECAPITULATION OF JOB PRICES BASED ON WORK ITEM TYPES

No	**Work Item**	**Total Cost (including VAT)**		**Difference**		**Weight (%)**
		Conventional (Rp)	**BIM TS (Rp)**	**Increase (Rp)**	**Decrease (Rp)**	
A	**Precast**					
1	Piling Work	445,280,000	445,280,000	-	-	0
B	**Cast in Place**					
1	Concrete fc=20 MPa	574,680,642	540,258,723	-	34,421,919	-5.99
2	Iron work	913,718,017	1,058,113,396	144,395,379	-	15.80
Total Main Structure Work Cost		1,933,679,000	2,043,653,000	109,973,460		5.69

There is no difference between the two calculation methods for precast concrete work, as the calculations involved are quite simple. That is, the required volume is only in linear meters, so only the total length of the piles needs to be calculated. However, for the cast-in-place concrete work, there is a significant difference, with a price variance of -5.99% (IDR 34,421,919) for fc=20 MPa concrete work, indicating that the value obtained using the BIM approach with TS is lower than that of the traditional approach. This discrepancy arises because, in the manual calculations for the slab, the intersection of columns and floors is not accounted for in detail, leading to a double counting of the volume in these areas. In contrast, the BIM application allows for more detailed modeling and calculations that can be organized to avoid overlaps with other objects.

The price difference in reinforcement work is quite substantial, amounting to 15.8% (IDR 144,395,379) based on all the types of reinforcement work. This indicates that the calculations using BIM applications yield higher estimates compared to the conventional methods. When analyzing the reinforcement work per floor, the value differences for each floor are: 23.67% for the first floor, 54.30% for the second floor, 19.04% for the third floor, and 2.99% for the rooftop. Such significant price discrepancies may be attributed to manual reinforcement calculations being conducted only in general terms without detailed considerations, such as the bending radius, and using the centerline of reinforcement rather than its outer edge, which affects the reinforcement calculation accuracy. In contrast, the modeling performed within the BIM application is more detailed regarding these aspects. Through a sufficiently detailed BIM approach, any changes in the rebar volume will be more accurate, minimizing errors related to excess or insufficient volume. However, there are also limitations in the modeling stirrups and plain bars within the Application and Component method that cannot instantaneously model certain elements, especially in beam modeling that requires separating several sections, rendering rebar modeling slightly more time-consuming. With the BIM approach, it is hoped that planning can align closely with the actual field implementation as it advances.

TABLE III. ANALYSIS PROCESS AND ACCURACY COMPARISON

Stages	Conventional Method	BIM
Planning	Adjust formats or formulas in existing Excel to shorten work time	Follows ironwork detailing rules
Implementation	Follows ironwork detailing rules	Follows ironwork detailing rules
Accuracy	Calculations with conventional approaches are not compatible with implementation in the field	Can be applied in the field

The analysis of the requirements for the concrete and reinforcement work based on the BIM method demonstrates that the latter is preferred due to its competence in terms of quality, time, and cost [21]. From a quality perspective, the BIM approach operates with greater detail, resulting in minimal rework while including accurate detailed drawings. The calculation of rebar requirements using the BIM method is faster than with conventional methods [3, 11, 21]. Tasks that are similar and repetitive are easier to manage with the BIM approach than with conventional/manual methods because the former is integrated from start to finish [21]. Concerning cost, the BIM method allows contractors to reduce expenses by approximately 1%-5%, because if the estimates provided by the planners are not detailed enough, the volumes may not align with the actual field conditions, leading to bids that are too low. This situation can be detrimental to contractors if the bid value is lower than the volume executed in the field. Furthermore, the BIM approach facilitates a smooth project progress without obstacles during the implementation phase.

In [22], two benefits of employing BIM throughout the life cycle of smart buildings are outlined. On the one hand, BIM facilitates information sharing and interchange by offering 3D visual models. Thus, BIM can help stakeholders collaborate and communicate data amongst tools from other disciplines. However, by examining and modeling the building performance, BIM can be combined with additional tools to address certain design issues. It also helps promote smart building and effectively regulate project cost, schedule, and environmental damage. Previous research indicates that BIM offers a comprehensive information model to address issues pertaining to smart buildings' whole life cycle.

IV. CONCLUSION

In the construction industry, traditional design methods often face challenges related to data integration and cost efficiency. The use of various non-integrated software leads to data incompatibility, resulting in increased costs and decreased construction quality. Therefore, Building Information Modeling (BIM) has emerged as an innovative solution that offers a 3D model-based approach to enhance efficiency and effectiveness in construction project planning. Although BIM has been widely adopted, a gap still remains in understanding how this method can significantly reduce costs and time in cost estimation compared to the conventional methods. Previous research often fails to directly compare the cost estimation results between these two methods in the context of real projects, particularly in Indonesia.

This study presents a novelty by conducting a comparative analysis between BIM-based cost estimation methods and conventional methods on the construction project of the Guntung Payung Community Health Center in Banjarbaru. Utilizing Tekla Structures (TS) software, the research demonstrates that cost estimation using BIM is more efficient and accurate than when employing conventional methods, with significant cost differences being noted in concrete and reinforcement work. By implementing the TS software, the analysis shows significant cost differences, specifically 12% (IDR 34,341,919) for concrete work and 13% (IDR 144,395,379) for rebar work.

The BIM method not only accelerates the estimation process but also produces more accurate calculations that align closely with the project needs. This suggests that the use of BIM technology can reduce the risk of cost overruns and enhance construction quality, thanks to better data integration and reduced inaccuracies in volume calculations.

The primary contribution of this research is the provision of empirical evidence of the advantages of BIM utilization in construction cost estimation. The findings indicate that BIM not only reduces the time required for estimation processes, but also improves the accuracy of cost calculations. This research can serve as an important reference for practitioners and academics in civil engineering to promote a broader adoption of the BIM technology in Indonesia's construction industry. Thus, this study highlights not only the potential of BIM to enhance construction project efficiency, but also fills the existing knowledge gap regarding its practical applications in the field.

REFERENCES

[1] T. A. Nguyen, T. A. Nguyen, and T. V. Tran, "Building Information Modeling (BIM) for Construction Project Schedule Management: A Review," *Engineering, Technology & Applied Science Research*, vol. 14, no. 2, pp. 13133–13142, Apr. 2024, https://doi.org/10.48084/etasr.6834.

[2] P. R. Adhi, A. Hidayat, and H. Nugroho, "Perbandingan Efisiensi Waktu, Biaya, Dan Sumber Daya Manusia Antara Metode Building Information Modelling (Bim) Dan Konvensional (Studi Kasus: Perencanaan Gedung 20 Lantai)," *Jurnal Karya Teknik Sipil*, vol. 5, no. 2, pp. 220–229, Jul. 2016.

[3] J. Ratajczak, M. Riedl, and D. T. Matt, "BIM-based and AR Application Combined with Location-Based Management System for the Improvement of the Construction Performance," *Buildings*, vol. 9, no. 5, May 2019, Art. no. 118, https://doi.org/10.3390/buildings9050118.

[4] D. Bryde, M. Broquetas, and J. M. Volm, "The project benefits of Building Information Modelling (BIM)," *International Journal of Project Management*, vol. 31, no. 7, pp. 971–980, Oct. 2013, https://doi.org/10.1016/j.ijproman.2012.12.001.

[5] M. Ridha and U. M. Musakkir, "Analisis Anggaran Biaya dan Waktu Optimal dengan Metode Least Cost Sheduling," *Jurnal Teknik Sipil Unaya*, vol. 4, no. 2, pp. 71–78, 2018, https://doi.org/10.30601/jtsu.v4i2.35.

[6] I. C. Napu, L. Wikarsa, and T. C. Suwanto, "Aplikasi Perhitungan Rencana Anggaran Biaya Pembuatan Rumah Tinggal Berbasis Web," *Jurnal Ilmiah RealTech*, vol. 13, no. 2, pp. 20–28, 2017.

[7] J. U. D. Hatmoko, M. A. Wibowo, F. Kristiani, R. R. Khasani, R. Fatmawati, and G. D. Sihaloho, "Edukasi Building Information Modeling (BIM) pada Kontraktor Kecil," *Jurnal Pasopati*, vol. 2, no. 3, pp. 198–202, Aug. 2020, https://doi.org/10.14710/pasopati.2020.6536.

[8] I. A. Bhatti, A. H. Abdullah, S. Nagapan, N. B. Bhatti, S. Sohu, and A. A. Jhatial, "Implementation of Building Information Modeling (BIM) in Pakistan Construction Industry," *Engineering, Technology & Applied Science Research*, vol. 8, no. 4, pp. 3199–3202, Aug. 2018, https://doi.org/10.48084/etasr.2145.

[9] P. M. Diaz, "Analysis of Benefits, Advantages and Challenges of Building Information Modelling in Construction Industry," *Journal of Advances in Civil Engineering*, vol. 2, no. 2, pp. 1–11, 2016, https://doi.org/10.18831/djcivil.org/2016021001.

[10] A. N. Hasan and S. M. Rasheed, "The Benefits of and Challenges to Implement 5D BIM in Construction Industry," *Civil Engineering Journal*, vol. 5, no. 2, pp. 412–421, Feb. 2019, https://doi.org/10.28991/cej-2019-03091255.

[11] C. Robinson, "Structural BIM: discussion, case studies and latest developments," *The Structural Design of Tall and Special Buildings*, vol. 16, no. 4, pp. 519–533, Dec. 2007, https://doi.org/10.1002/tal.417.

[12] R. Ferial, B. Hidayat, R. C. Pesela, and D. Daoed, "Quantity take-off berbasis building information modeling (bim) studi kasus: gedung bappeda padang," *Jurnal Rekayasa Sipil (JRS-Unand)*, vol. 17, no. 3, pp. 228–238, Feb. 2022, https://doi.org/10.25077/jrs.17.3.228-238.2021.

[13] A. A. Alfahad and A. M. Burhan, "BIM-Supporting System by Integrating Risk Management and Value Management," *Engineering, Technology & Applied Science Research*, vol. 13, no. 6, pp. 12130–12137, Dec. 2023, https://doi.org/10.48084/etasr.6427.

[14] A. Husen, *Manajemen proyek*. Yogyakarta, Indonesia: Andi, 2011.

[15] A. Monteiro and J. Pocas Martins, "A survey on modeling guidelines for quantity takeoff-oriented BIM-based design," *Automation in Construction*, vol. 35, pp. 238–253, Nov. 2013, https://doi.org/10.1016/j.autcon.2013.05.005.

[16] R. Becvarovska and P. Matejka, "Comparative analysis of creating traditional quantity takeoff method and using a BIM tool," in *Construction Maeconomics Conference*, Prague, Czech Republic, Nov. 2024, pp. 1–4.

[17] D. Laorent, P. Nugraha, and J. Budiman, "Analisa quantity take-off dengan menggunakan autodesk revit," *Dimensi Utama Teknik Sipil*, vol. 6, no. 1, pp. 1–8, Apr. 2019, https://doi.org/10.9744/duts.6.1.1-8.

[18] M. Valinejadshoubi, O. Moselhi, I. Iordanova, F. Valdivieso, and A. Bagchi, "Automated system for high-accuracy quantity takeoff using BIM," *Automation in Construction*, vol. 157, Jan. 2024, Art. no. 105155, https://doi.org/10.1016/j.autcon.2023.105155.

[19] A. Oli, "Structural BIM Modelling Using Tekla Structures: Focus On A Modelling Process Of An Office Building," BSc thesis, Metropolia University of Applied Sciences, Helsinki, Finland, 2017.

[20] S. I. Setiyaningsih, "Perhitungan Struktur Beton dan Perbandingan Perhitungan Biaya Menurut SNI DT 91-00008-2007 dan SK SNI T-15-1991-03 (Studi Kasus Gedung Bina Marga Dan Cipta Karya Kabupaten Aceh Besar): Calculation of Concrete Structures and Comparison of Cost Calculations According to SNI DT 91-00008-2007 and SK SNI T-15-1991-03 (Case Study of Bina Marga Building and Cipta Karya of Aceh Besar District)," *Anterior Jurnal*, vol. 12, no. 2, pp. 23–33, Jun. 2013, https://doi.org/10.33084/anterior.v12i2.303.

[21] L. T. Soon, L. S. Wong, M. A. Kamarazaly, C. C. Saar, and H. S. Ilmi, "Comparison of bim-based quantities take-off in quantity surveying profession," *Journal of the Malaysian Institute of Planners*, vol. 22, no. 3, pp. 150–164, Jul. 2024, https://doi.org/10.21837/pm.v22i32.1499.

[22] A. Yang, M. Han, Q. Zeng, and Y. Sun, "Adopting Building Information Modeling (BIM) for the Development of Smart Buildings: A Review of Enabling Applications and Challenges," *Advances in Civil Engineering*, vol. 2021, no. 1, Jan. 2021, Art. no. 8811476, https://doi.org/10.1155/2021/8811476.