Integration of Building Information Modelling in Quantity Take-Off for Structural Work of Buildings

Hari Eko Raharjo[1], Siti Nurasiyah[1] and Istiqomah[1]
[1] Civil Engineering Study Program, Indonesian University of Education
*Corresponding Author: Hari Eko Raharjo. Email: hariekra@upi.edu

Abstract

The advancement of technology in the construction industry has encouraged the adoption of digital methods in project planning and management. Building Information Modelling (BIM) supports construction digitalization by integrating building data, scheduling, and cost estimation. A comparison between conventional and BIM-based methods for structural work volume using Autodesk Revit 2024 shows differences in quantities for concrete (5.1%), reinforcement (7.73%), and formwork (2.3%). Workforce planning was carried out using the resource levelling method in Microsoft Project, resulting in 207 workers required in weeks 1 and 2, with a total duration of 50 working days. Budget comparison indicates a cost difference of 5.06% lower when using the BIM-based method. All data were then integrated into Navisworks to produce a time-based 4D simulation of the building construction sequence.

Keywords: Building Information Modelling, Quantity Take Off, Superstructure

I. Introduction

The advancement of information technology has driven a significant transformation in the construction industry, particularly through the implementation of Building Information Modeling (BIM). BIM enables cross-disciplinary integration within a single digital model, fostering collaboration, efficiency, and accuracy in project planning and execution. One of the key applications of BIM lies in Quantity Take Off (QTO) for estimating material volumes, which in Indonesia is often still conducted using conventional methods prone to errors.

The advancement of information technology has driven a significant transformation in the construction industry, particularly through the implementation of Building Information Modeling (BIM). BIM enables cross-disciplinary integration within a single digital model, fostering collaboration, efficiency, and accuracy in project planning and execution. One of the key applications of BIM lies in Quantity Take Off (QTO) for estimating material volumes, which in Indonesia is often still conducted using conventional methods prone to errors.

This study aims to examine the integration of BIM in QTO calculation and resource leveling analysis to produce more accurate, efficient, and competitive building project planning in the era of digital construction.

1.1. Building Information Modelling (BIM)

Building Information Modeling (BIM) is an integrated digital model that contains all building information throughout the project lifecycle. This technology enhances construction management efficiency by optimizing processes from planning to maintenance. Its implementation requires a strong legal foundation, particularly in BIM-based contracts, as well as model data validation to ensure security, prevent data loss, and minimize the risk of information manipulation during the design process (1). BIM has become a vital tool supporting the digital transformation in the planning and execution of modern construction projects (2).

BIM offers significant benefits, such as interactive 3D visualization and integrated project information management. One of its main advantages is the ability to detect design clashes before construction begins, thereby improving effectiveness and efficiency—particularly in the modeling of structural and architectural elements. In addition, BIM supports more accurate estimations of project duration, material quantities, and construction costs, making it a highly efficient tool for project managers (2).

The adoption of BIM faces several challenges, particularly the high initial costs associated with software and human resource training. In Indonesia, these obstacles are further compounded by the limited availability of BIM experts and the low interest among small to medium-sized contractors, who continue to rely on conventional methods (3). Regulatory limitations present an additional barrier to BIM adoption in Indonesia, alongside technical and cost-related challenges. In contrast to the United Kingdom, which has mandated BIM since 2011 and recorded an increase in adoption from 10% to 70% by 2018, Indonesia has only implemented it on a limited scale. This situation highlights the urgent need for stronger support from both the government and the construction industry to accelerate and expand BIM implementation across various construction projects (4).

1.1.1. Dimensi BIM

BIM has undergone significant advancements in its development. This innovative approach has transformed the construction industry by providing a platform for project planning and execution. The advantages of BIM in managing project information are categorized into multiple dimensions. These dimensions not only include the physical representation of the building but also incorporate other critical aspects such as time and cost. (5).

Table 1. Dimensions BIM

Jenis BIM	Fungsi
BIM 3D	refers to a building model that includes information parameters, more detailed components, and the ability to be integrated with various platforms for enhancement into higher dimensions (modeling).
BIM 4D	Can be integrated with construction scheduling data to enable time-based simulations.
BIM 5D	*Supports Quantity Take Off and cost estimation, encompassing quantities and unit prices, which can be collaboratively managed.*
BIM 6D	Enables energy analysis for sustainable buildings (building sustainability), allowing collaboration in environmental performance assessments.
BIM 7D	Represents the use of 3D modeling based on an Asset Information Model (AIM), facilitating the retrieval of non-graphical and alphanumeric information.
BIM 8D	Involves building maintenance data (facility management applications), typically used during the operational and maintenance phases, and can be integrated for efficient long-term asset management.

1.1.2. Autodesk Revit

Revit is a BIM-based software that supports architectural, structural, and MEP (Mechanical, Electrical, and Plumbing) disciplines in construction projects. Through integrated 3D modeling, Revit provides detailed information on elements such as materials, costs, and technical specifications, thereby promoting more effective cross-disciplinary collaboration (6). Revit is a BIM-based software that offers various functional advantages in supporting the planning and execution of construction projects. One of its main features is the ability to provide real-time realistic 3D visualization, offering a comprehensive and accurate representation of the building. This is further enhanced by rendering capabilities for professional presentation purposes.

Revit also supports multi-disciplinary integration, enabling simultaneous collaboration among architects, structural engineers, and MEP professionals within a centralized model, thereby reducing the risk of miscommunication between teams. Through its parametric component system (families), users can modify, define dimensions, and customize building elements according to specific project requirements.

In terms of interoperability, Revit is capable of reading and exporting various file formats such as DWG, DXF, DGN, and IFC, thereby supporting integration with other software like AutoCAD, Navisworks, and structural analysis programs. Its Bill of Quantity (BOQ) or scheduling feature enables the automatic identification and calculation of components such as the number of doors, windows, and furniture items.

In addition, Revit enables optional design exploration, making it easier to compare design alternatives based on both quantitative analysis and visual assessment. The technical documentation process is also more efficient, as the system automatically generates working drawings, sections, and material schedules directly from the model.

Finally, the Material/Quantity Take Off feature allows for detailed and rapid calculation of material volumes, which greatly supports cost estimation and enhances project execution efficiency (7).

1.2. Quantity Take Off (QTO)

Quantity Take Off (QTO) is the process of calculating the volume of materials required in a construction project. Traditionally, QTO is performed manually and is prone to errors. However, with a BIM-based approach, quantity estimation can be carried out in a more detailed, faster, and accurate manner through direct integration with the digital building mode (8). The calculation of work volumes in a construction project typically includes several types of work, such as preparatory work, earthworks, structural work, architectural work, electrical work, and plumbing work.

2. METHOD

This research employs a descriptive quantitative analysis method, tailored to variables related to resource and material distribution in construction projects. The collected data are presented in meaningful numerical form, aiming to objectively describe resource management. This approach enables a comparative analysis between conventional methods and BIM-based methods in Quantity Take Off (QTO) estimation, thereby identifying solutions to issues of material calculation efficiency and resource management in project execution.

2.1. Study Case Location

This research was conducted at the construction project of the New Faculty of Economics and Business Building at Universitas Jenderal Achmad Yani, located on Jalan Terusan Jenderal Sudirman, Cibeber, South Cimahi District, Cimahi City, West Java 40525. This project was selected as a case study because it represents a multi-story building project with resource management complexity and material estimation challenges that are highly relevant for analysis using the Building Information Modeling (BIM) approach.

2.2. Research Data

This research utilizes secondary data obtained from the construction project of the New Faculty of Economics and Business Building at Universitas Jenderal Achmad Yani. The data includes the building's Detail Engineering Design (DED) drawings, the project's S-curve, manpower data, and the Unit Price Analysis (AHSP). These documents were acquired through collaboration with the contractor, who holds the official project records. Additionally, the collection of secondary data is supported by a literature review comprising academic sources such as textbooks, journals, and relevant online references to strengthen the theoretical foundation and research context.

2.3. Stages of Reasearch

The modeling process begins with the creation of grids in Revit Structure as an initial step to facilitate the systematic and precise drawing of structural elements. Once the grids are established, the next step is to define the levels to represent the number of floors and set the base elevation layout, including the foundation arrangement. The modeling then proceeds by creating the primary structural elements—beams and columns—based on the dimensions and sizes specified in the design drawings. This is followed by the modeling of floor slabs and bore pile foundations, using appropriate dimensions and technical specifications as references.

The next stage involves reinforcement modeling for each structural element, which is carried out based on standardized rebar detailing. Once all elements have been fully modeled in both 2D and 3D, the process continues with work volume calculation (5D), enabling automatic and accurate material quantity estimation directly from the model.

3. Results and Discussion

This study presents a comparison of structural work volumes between the manual (conventional) method and the Building Information Modeling (BIM)-based method using Revit software. Overall, the results indicate that volume calculations performed with Revit tend to be more efficient and accurate than those obtained through manual methods.

In the reinforcement work, the column elements showed a volume difference of 16.42%, followed by beams at 1.71%, and slabs at 5.15%. These discrepancies highlight the sensitivity of BIM in capturing the dimensions and details of structural elements comprehensively and with precision, particularly in areas that are difficult to detect using two-dimensional methods..

For concrete work, volume calculations using Revit also yielded more efficient results. The column elements showed a difference of 10.42%, beams 10.25%, and slabs 0.33%. These findings indicate that the manual method has the potential to overlook minor details, particularly in structural elements with complex shapes or joints that are not clearly visible in 2D drawings.

Meanwhile, in formwork work, the volume differences between the two methods showed relatively small deviations. Columns had a deviation of 2.31%, beams 4.51%, and slabs 0.34%. Although the conventional method still produced results close to those obtained through Revit, these findings demonstrate that BIM is capable of delivering more consistent and reliable volume estimations.

A. Element Cutting

The volume differences in concrete between the BIM and conventional methods are caused by overlaps in certain elements. These overlaps are automatically trimmed and excluded from the calculation by Revit software. For instance, in beam elements, the structural beams are directly intersected and trimmed by the slabs and columns.

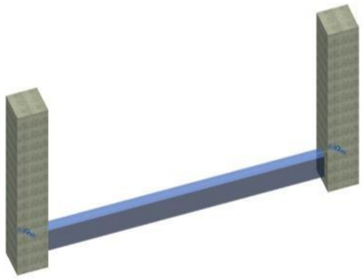

Figure 1. Example of Overlapping Case

Revit automatically trims elements that experience overlap. As shown in Figure 2, the beam is visibly intersected and trimmed by the column element, resulting in a reduced beam volume. The conventional calculation method produces a volume that is approximately similar to that obtained through the BIM method, with both yielding closely comparable results. Therefore, it can be concluded that Revit calculates volume by subtracting the overlapping portions of intersecting elements.

B. Differences in Stirrup Calculation Result

The conventional calculation resulted in 69 stirrups with a total weight of 78.64 kg, whereas the modeling results using Revit showed 64 stirrups with a total weight of 71.94 kg. This difference reflects greater efficiency in quantity and higher accuracy in BIM-based calculations.

Table 2. Beam Stirrup Reinforcement Iron

Host Mark	Bar Diameter	Berat Per m	Quantity By Rebar Set	Bar Length	Panjang Total	Berat
B 300x700 Lantai 1	10 mm	0.62 kg/m	18	1.818 m	32.721 m	20.17 kg
B 300x700 Lantai 1	10 mm	0.62 kg/m	23	1.818 m	41.810 m	25.78 kg
B 300x700 Lantai 1	10 mm	0.62 kg/m	18	1.818 m	32.721 m	20.17 kg
			64		107.251 m	66.12 kg

The comparison indicates a difference in the weight of stirrup reinforcement, which in turn leads to a discrepancy in the volume of rebar calculated.

The output results from both methods were further processed to generate a planned budget estimate (RAB). These costs were then compared to determine the percentage difference between the two methods. Cost calculations were carried out using unit price analysis and basic unit prices. The conventional method yielded a total estimated cost of IDR 8,844,817,121.59, while the BIM-based method produced a lower cost of IDR 8,397,092,121.78. Therefore, it can be concluded that the BIM method results in a lower overall cost compared to the conventional approach. The comparison between the two methods shows a difference of IDR 447,724,999.80, or 5.06%..

4. Conclusions

The research findings reveal a significant difference between the conventional and BIM methods in terms of volume calculation, scheduling, and project budgeting. Structural work volumes calculated using BIM tend to be lower, with a deviation of 4.95% in concrete, 8.02% in reinforcement, and 2.3% in formwork, due to BIM's ability to provide a more accurate 3D representation compared to manual approaches. From a budgeting perspective, BIM also achieved cost efficiency of approximately IDR 454 million, or a deviation of 5.14%, particularly in column and beam works, thanks to its capability to detect overlapping volumes and precise cutting lengths. Overall, BIM has proven to offer advantages in calculation accuracy, time efficiency, and construction cost control.

ACKNOWLEDGMENT

The author would like to express sincere gratitude to Dr. Siti Nurasiyah, S.T., M.T., as the first academic advisor, and to Mrs. Istiqomah, S.T., M.T., as the second academic advisor, for their patience, guidance, and continuous support throughout the preparation of this proposal. The author also extends appreciation to fellow students of the 2021 cohort, especially the "Senam Bareng" family, for their active support and valuable input during this process. Lastly, the author wishes to acknowledge their own perseverance and commitment in completing this final project to the best of their ability.

REFERENCES

1. Santoso IS, Suroso A, Amin M. Pengaruh Tingkat Penerapan BIM 5D Terhadap Kinerja Biaya Proyek Konstruksi. Konstruksia. 2023;14(2):83.
2. Azhar S. Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadersh Manag Eng. 2011;11(3):241–52.
3. John R, Heap-Yih C, Christopher P. Adoption of Building Information Modelling technology (BIM). Eng Constr Archit Manag. 2015;22(1):91–107.
4. Malleson A. National BIM Report 2018 - Reino Unido. 2018;9–27.
5. Sabil D, Erizal. Penerapan Buidling Information Modeling (BIM) 5D pada Proyek Gedung Simpang Temu Dukuh Atas, Jakarta Pusat. J Tek Sipil dan Lingkung. 2023;8(02):95–104.
6. Reviana. Penerapan Building Information Modeling (BIM) Menggunakan Software Autodesk Revit 2019 pada Pekerjaan Non Struktur (Studi Kasus : Gedung B Fakultas Ekonomi dan Bisnis Universitas Lampung). Skripsi. 2023;13(1):104–16.
7. Lu Y, Wu Z, Chang R, Li Y. Building Information Modeling (BIM) for green buildings: A critical review and future directions. Autom Constr. 2017;83:134–48.
8. Asih WR, Husni HR, Niken C. Perbandingan Quantity Take Off (QTO) Material Berbasis Building Information Modeling (BIM) Terhadap Metode Konvensional pada Struktur Pelat. J Rekayasa Sipil Dan Desain. 2022;10(4):563–74.