International Journal of Architecture and Urbanism Vol. 08, No. 02 (2024) 184 – 190

International Journal of Architecture and Urbanism

Journal homepage: https://talenta.usu.ac.id/ijau

Quantity Take Off Comparison Using Building Information Modelling (BIM) with Autodesk Revit Software and Traditional Method

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ARTICLE INFO

Article history:
Received 5-4-2024
Revised 27-7-2024
Accepted 8-8-2024
Available online 31-8-2024

E-ISSN: 2622-1640
P-ISSN: 2622-0008

How to cite:
Simatupang et al. Quantity Take Off Comparison Using Building Information Modelling (BIM) with Autodesk Revit Software and Traditional Method. International Journal of Architecture and Urbanism. 2024. 8(2):184-190.

http://doi.org 10.32734/ijau.v8i2.16146

ABSTRACT

In recent years, the development of technological innovations has grown rapidly in various aspects including the construction projects. The construction industry has been significantly impacted by the availability of technological development, namely Building Information Modelling (BIM) who play a big role in accommodating a more efficient and collaborative approach in construction projects. Common problems in construction projects include delays, rework, or errors in calculating the required quantities and these issues can lead to time and cost overruns. These problems can be minimized by utilizing BIM. In this research, a comparative analysis between traditional methods and BIM methods (Autodesk Revit) is carried out. Based on the data that has been analyzed, it is found that the BIM results are smaller than the traditional project results with a percentage comparison difference of 8.61% for the volume of concrete volume, and 6% for the weight of reinforcement. It can be inferred that this precision in BIM's quantity take-off not only modernizes adjustments but also enhances project efficiency, showcasing the innovative and substantial impact of BIM on contemporary construction methods.

Keywords: BIM (Building Information Modelling), Quantity Take off, Revit.

1. Introduction

Traditional construction methods often face challenges like delays, rework, and inaccurate quantity calculations in construction projects [1]. These issues can lead to substantial budget overruns and schedule delays, which then will ultimately reduce the productivity and financial viability of construction projects[2]. To address these challenges, various approaches including technological innovations have been employed. One of these construction technology innovations is Building Information Modeling (BIM). As a significant improvement in the AEC industry, BIM provides digital construction or virtual models of buildings, which can be applied throughout the project state from planning, design, construction, and facility operation[3]. The construction industry has been significantly impacted by the availability of Building Information Modelling who play a big role in accommodating a more efficient and collaborative approach in construction projects, predominantly in designing the building, construction stage and project management [4].

One of the key features of BIM is the use of artificial intelligence (AI) in which these algorithms analyze project data to predict problems, improve resource use, and make scheduling more accurate.[5]. Theories on BIM in construction industry emphasize its role in improving collaboration, simplifying design and building processes, and boosting project efficiency and quality through collaborative management and optimization tools such as IFC-based design and multi-objective genetic algorithms [6]. BIM technology enables the creation of detailed 3D models that comprehend all aspects of a building project which allows the stakeholders to visualize and simulate the construction process before it begins [7]. BIM technologies have received popularity compared to the traditional methods such as computer-aided design (CAD) because they can manage various stages of a building's lifecycle, from design and construction to monitoring [7].

The construction industry has been dramatically transformed by BIM as BIM creates a unified system that connects everything from design and construction to maintenance [8]. Nevertheless, the practices of BIM in the construction industry which has adopted BIM has been slow due to various barriers or obstacles in some regions, [9]. For instance, traditional construction methods face major challenges, such as the complexity and uncertainty of onsite processes, which can be influenced by site conditions, weather, and regional factors[10]. The methodology of BIM creates digital 3D models that centralize information, making it easier for collaborators to access and share data throughout a building's lifecycle; however, ensuring different systems work together smoothly is still a challenge to overcome [11]. Moreover, Lee et al [12] also state that related factors such as tender documents, human resources, and BIM software all impact project cost performance, eventually will influence the successful application of BIM. Nevertheless, despite the challenges in its adoption, BIM has significantly improved project coordination and overall project quality, and has succesfully highlighted its potential in the construction sector.

One software based on the BIM method is Autodesk Revit. Revit is a powerful software widely used in the engineering, construction and architecture industry for BIM [13]. Autodesk Revit can be used for project management and control, drawing of the projects and calculations of work volume; Autodesk Revit software also offers features for designing architectural elements, MEP, building structures and these features can facilitate improved coordination among specialists from various fields[14]. By using Revit, contractors have the advantage of being able to increase efficiency in planning time and utilization of human resources, hence it will minimize the design life cycle, high quality and accurate documentation of the construction process[15].

In line with this, using Revit BIM software allows for easy collaboration among project stakeholders, encouraging quick communication and coordination. This streamlines decision-making and boosts overall project efficiency[16]. Also, Revit as the BIM technology enables stakeholders to generate intricate 3D models of construction projects, facilitating improved teamwork, visualization, and decision-making during the entire project duration[17]. The use of BIM software such as Revit has greatly improved cooperation between parties involved, streamlined design and construction processes, and boosted the effectiveness and excellence of projects [18]. Another feature is the clash detection. The clash detection feature in BIM software helps users find and fix conflicts between different parts of a building project[19]. With clash detection analysis, BIM software like Autodesk Revit can identify conflicts between structural elements, MEP systems, architectural features, and other parts of a building project [20].

In relation to the problem earlier, common problems in construction projects include delays, rework, and errors in calculating the required quantities and these issues can lead to time and cost overruns. Therefore, it can be inferred that using Building Information Modelling (BIM) in construction management will lead to the improvement in quality, efficiency and workflows; this highlights its importance as a crucial tool in modern construction projects [21]. This research aims to compare the volume calculations obtained using BIM Autodesk Revit with those from the Bill of Quantity for structural work in the Classroom Construction project at SMPN 31 Medan. Furthermore, it seeks to evaluate how effectively Autodesk Revit assists in performing quantity take-off calculations for this project.

2. Method

In this research, comparative research methods and quantitative approaches were employed. This research aims to compare the results of quantity calculations obtained using BIM compared to traditional methods.

2.1 Location of the research

This research was carried out on the new classroom construction project at SMPN 31 Medan, Jl. Jamin Ginting, North Sumatra. The construction project can be seen on figure 1.

Figure 1 New classroom Construction project at SMPN 31 Medan (Source: primary data, 2023)

2.2 Modeling with BIM Autodesk Revit

To carry out analysis of work quantity calculations using the BIM method, structural element modeling is done in Autodesk Revit BIM software. The modeling steps in Autodesk Revit's BIM software involve selecting a construction template for structural modeling, focusing on volume calculations rather than structural, architectural, and MEP analysis. Grids are then drawn based on the input plan using the Structure → Grid function. Elevation drawings are created by choosing an elevation from the project browser and using Structure → Level to indicate the building's elevation. Columns, beams, and floor plates are modeled according to detailed work drawings, utilizing Structure → Column for columns, Structure → Beam for beams, and Structure → Floor for floor plates. Customizing column shapes, beam types, and floor slab sizes are done by selecting the desired options in the properties section. The positioning of columns, beams, and floor plates is based on the working drawings. Rebar reinforcement is added to beams and columns by selecting rebar from the modify toolbar. Similarly, reinforcement is added to floor plates by selecting the area from the modify toolbar. Clash detection can be performed by running an interference check under Collaborate → Interference Check → Run Interference Check. Checking for collisions between Structural Columns and Structural Framing is important in ensuring the accuracy of the modeling. If no collisions are found, the modeling process is considered to be correct.

2.2.1 Comparative Analysis of Traditional Methods and BIM Revit

In calculating the efficiency value of the traditional method and BIM Autodesk Revit, a comparison formula for the two methods is used. To calculate efficiency, the following equation can be used:

$$\% \, Comparison = \frac{Difference}{Traditional \, Method} \times 100\%$$

where: Difference = Traditional method results – BIM results

3. Results and Analysis

3.1 Output Quantity

To generate quantity outputs in Revit, begin by accessing View → Schedule/Quantities. Next, apply filters by selecting Structure from the Filter list and then choose Structural Columns to name the schedule "Column Concrete Volume". Select relevant parameters and finalize by clicking OK to view volume results. Arrange these results under Properties → Sorting/Grouping to organize them as needed. To display total volumes, adjust Schedule Properties under Formatting → Volume and configure calculations for cumulative totals. Repeat these steps for beams, selecting Structural Framing and naming the schedule "Beam Concrete Volume", and for floor plates, selecting Floors and naming it "Floor Plate Concrete Volume". This process ensures accurate reporting of quantities for columns, beams, and floor plates in Revit.

Table 1 Output Quantity of Column, Beam, and Floor Plate

No.	Work Item	BIM Volume (m^3)
1	Column K1	43,52
2	Column K2	3,47
3	Beam B1	9,336
4	Beam B2	18,880
5	Beam B3	4,592
6	Beam BA1	5,805
7	Beam BA2	11,562
8	Beam BA3	1,520
9	Floor Plate	53,76675

Table 1 gives a breakdown in detail of the volumes of various structural elements as calculated by BIM. Column K1 is the largest at 43.52 m^3, while Column K2 is much smaller at 3.47 m^3. Among the beams, Beam B2 has the highest volume at 18.880 m^3, and Beam BA3 has the smallest at 1.520 m^3. The floor plate has the largest volume overall at 53.76675 m^3. This breakdown helps in understanding the material needs for each part of the project.

3.2 Reinforcement Weight Output

To obtain accurate output quantities, repeat the output quantity stages with differences in the 2nd and 3rd stages. In the 2nd stage, select Structural Rebar for Reinforcement, then give the name Reinforcement Weight. Then in the third stage add the Reinforcement Volume parameter and add *formula* (f_x) = *Reinforcement Volume* × 7850 kg/m^3. This process will give the output weight of beam, floor plate reinforcement and column.

Table 2 The output weight of beam, floor plate reinforcement and column

No.	Work Item	BIM Volume (*Kg*)
1	Column K1	7864,78
2	Column K2	564,88
3	Beam B1	1133,01
4	Beam B2	3155,44
5	Beam B3	765,13
6	Beam BA1	826,60
7	Beam BA2	2830,91
8	Beam BA3	380,50
9	Floor Plate	8148,22

Table 2 lists the weights of various structural elements as calculated by BIM. Here, Column K1 is the heaviest at 7,864.78 kg, while Column K2 is lighter at 564.88 kg. Among the beams, Beam B2 is the heaviest at 3,155.44 kg, and Beam BA3 is the lightest at 380.50 kg. Meanwhile, the floor plate has the largest weight overall at 8,148.22 kg.

3.3 Comparative Analysis of BIM and Traditional method Results

Table 3 shows the Comparative Analysis of Concrete Work Volumes. The table compares concrete volumes for various work items using BIM, traditional methods, and project estimates.

Table 3 The output weight of column, beam and floor plate reinforcement

No.	Work item	Volume of Concrete work (m^3)		
		BIM	Traditional	Project
1	Column K1	43,52	43,52	43,52
2	Column K2	3,47	3,47	4,16
3	Beam B1	9,336	9,336	9,88
4	Beam B2	18,88	18,88	20,01
5	Beam B3	4,592	4,592	4,88
6	Beam BA1	5,805	5,805	5,81
7	Beam BA2	11,562	11,562	12,36
8	Beam BA3	1,52	1,52	1,56
9	Floor Plate	53,76675	53,76675	64,64
	Total	152,45	152,45	166,82

Column K1 has the same volume of 43.52 m³ from both methods. Column K2 is 3.47 m³ in BIM and traditional methods, but 4.16 m³ in the project estimate. For beams, BIM and traditional methods volumes are similar, however project estimates are slightly higher. The floor plate is estimated at 64.64 m³ in the project, compared to 53.77 m³ in BIM and traditional methods. The total concrete volume is 152.45 m³ for both BIM and traditional methods, but 166.82 m³ for the project estimate. From this table we can see differences in concrete volume estimates between methods.

Comparison of percentage (%) calculation:

Difference = Project Volume – BIM Volume = 166.82 – 152.45 = 14.37 m^3

% volume comparison = Difference / Project volume × 100% = 14.37 m^3 / 166.82 m3 × 100% = 8.61%

When comparing the concrete volume estimates between BIM and the actual project, it is found that BIM's estimate was 8.61% lower, with a difference of 14.37 m³ (BIM estimated 152.45 m³ while the project used 166.82 m³). This highlights BIM's accuracy in volume calculation, improving construction planning and execution. Table 4 shows the output weight of reinforcement for columns, beams, and floor plates.

Table 4 The output weight of column, beam and floor plate reinforcement

No.	Work Item	Reinforcement Weight (*Kg*)		
		BIM	Traditional	Project
1	Column K1	7864,78	8035,26	8198,37
2	Column K2	564,88	606,59	748,06
3	Beam B1	1133,01	1157,55	1174,64
4	Beam B2	3155,44	3228,92	3284,80
5	Beam B3	765,13	803,06	820,79
6	Beam BA1	826,60	844,47	861,97
7	Beam BA2	2830,91	2809,12	2863,51

8	Beam BA3	380,50	417,58	424,74
9	Floor Plate	8148,22	8205,40	8931,61
	Total	Total	26107,95	27308,49

For Column K1, BIM is 7,864.78 kg, traditional method is 8,035.26 kg, and the project estimate is 8,198.37 kg. Column K2 weighs 564.88 kg in BIM, 606.59 kg traditionally, and 748.06 kg in the project estimate. Beam weights and the floor plate also have higher estimates in the project compared to BIM and manual calculations. Overall, BIM totals 26,107.95 kg, while the project estimate is 27,308.49 kg, showing differences between the methods.

Comparison of percentage (%) calculation:

Below is the formula of comparison of percentage (%) calculation, namely:

Difference = Project reinforcement weight – BIM reinforcement weight = 27308.49 – 25669.46 = 1639.03

% volume ratio = Difference / Weight of project reinforcement × 100% = 1639.03 / 27308.49 × 100% = 6%

The comparison between the weight of beam reinforcement in BIM and the project revealed a 6% reduction, indicating that BIM estimated a lower weight by 1639.03 kg compared to the project's weight of 27308.49 kg. This difference underscores BIM's ability to provide more precise estimations, contributing to improved accuracy in construction planning and execution.

4. Conclusion

Based on the findings from analyzing structural components like columns and beams using Building Information Modeling (BIM), the following conclusions can be drawn. The findings indicate a reduction of 8.61% in concrete volume and 6% in reinforcement weight compared to traditional methods, indicating 14.37 m^3 less concrete and 1639.02 kg lighter reinforcement. BIM’s capability to generate precise 3D models plays a crucial role in reducing errors, which may include human mistakes in calculating volumes and weights. Its features, like clash detection, help in identifying and resolving issues early in the planning phase. This precision in BIM's quantity take-off not only modernizes adjustments but also enhances project efficiency, showcasing the innovative and substantial impact of BIM on contemporary construction methods.

5. Acknowledgment

The authors extend their gratitude to all the stakeholders who have supported and contributed to this research.

6. Conflict of Interest

The authors declare that there are no conflicts of interest to report.

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