Quantity Takeoff Using Building Information Modeling on Superstructure Works

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Abstract

Technological advancements in the construction industry have encouraged the adoption of Building Information Modeling (BIM) as a digital approach in project implementation. This study discusses the implementation of BIM in calculating work volumes (Quantity Takeoff/QTO) and project scheduling by considering labor fluctuations through resource leveling analysis. The objective of this research is to compare QTO results between BIM and conventional methods, as well as to analyze labor requirements and project duration. This research uses a case study method on the superstructure phase of a building project. The comparison results show a difference in work volumes between the BIM and conventional methods, namely 8.98% for reinforcement work, 13.23% for concrete casting, and 8.57% for formwork. Additionally, the resource leveling analysis shows a labor requirement of 148 workers, with the superstructure work duration shortened to 56 days from the initial plan of 60 days. Based on these findings, this study provides a quantitative overview of the differences between the conventional and BIM-based methods in terms of work volume calculation and resource planning. Further studies are recommended using more diverse case objects and a broader scope of construction work.

Keywords: Building Information Modelling, Quantity Take Off, Superstructure

1. INTRODUCTION (HEADING 1)

Quantity Take Off (QTO) calculation is one of the critical stages in a project's life cycle. This calculation is carried out to determine the work volumes, which in turn serves as the basis for estimating the project budget. Conventionally, QTO is performed using manual methods by calculating the dimensions of each construction element. Typically, this process involves the use of several software tools, but the manual approach is considered inefficient and prone to errors, which may disrupt the execution of construction projects.

Technological advancements in the construction sector have rapidly accelerated, creating new opportunities for integrating digital tools. One such innovation increasingly adopted in Indonesia is Building Information Modeling (BIM). BIM plays a significant role in the construction industry as a technological approach that enhances the management and execution of construction activities.

QTO can be carried out using BIM-based technology, which generates work volume outputs directly from the 3D model created within the software. One of the most widely used BIM tools in Indonesia is Autodesk Revit, while other emerging alternatives include Tekla, Cubicost, and various similar platforms. BIM-generated models offer both visual representation and automated QTO calculations performed by the software. When design changes occur, the model can be updated accordingly, and the QTO results are automatically adjusted. This automation significantly reduces the time required for recalculating volumes during design revisions.

This study represents a form of adaptation to technological developments within the construction industry. The emergence of BIM-based QTO provides the industry with alternative methods for determining project costs. Therefore, it is essential to conduct research that identifies the most suitable QTO method for construction implementation. Such studies are necessary to align construction practices with technological advancements. Choosing the appropriate method enables more accurate and realistic cost estimation. The objective of this research is to identify the differences in QTO results and cost estimates between BIM-based and conventional methods. In this study, BIM is utilized to generate work volumes, specifically focusing on the superstructure works.

1.1. Building Information Modelling (BIM) (Heading 2)

The term Building Information Modeling (BIM) has many interpretations and definitions. It refers to the process of creating and managing information about a construction project throughout its lifecycle. BIM can be defined as a modeling technology and a set of related processes used to produce, communicate, and analyze building models. (1). The conceptual design phase is one of the initial stages in designing a building. It includes the development of building plans, massing, and general appearance, such as building orientation, structure, and basic program layout. BIM can have a significant impact on strengthening the quality of decisions made during this phase.

The features of BIM facilitate the assessment of design processes and the management of all operations in the built environment, while simultaneously offering a comprehensive database comprising geometric and non-geometric information (2). BIM technology, with its wide range of functions applicable in the construction industry, offers several advantages. According to a study conducted by Nelson and Jane, based on surveys of various construction projects, BIM provides numerous benefits throughout both the planning and execution phases. BIM enables early detection of design conflicts, fast and comprehensive delivery of building information, and accurate and consistent visualizations. The BIM model facilitates cross-disciplinary collaboration and automatically updates drawings when design changes occur. Furthermore, BIM supports early-stage cost estimation, assists in decision-making, and enhances model quality and alignment between design and implementation (3).

Building Information Modeling (BIM) technology consists of several dimensions, beginning with the most fundamental, which is 2D—representing construction drawings in a flat plane. Subsequently, the 3D dimension enhances the information by providing a three-dimensional visualization of the building model. This model can be developed using various software applications such as Revit, AutoCAD, Tekla, and others (4).

1.1.1. Autodesk Revit

Autodesk Revit is a Building Information Modeling (BIM) application developed to support structural calculation and engineering processes, while also providing integrated features for detailers, fabricators, manufacturers, and contractors. Revit not only enhances visualization and design capabilities, but also incorporates technical aspects such as structural logic, cost estimation, and project management. This application is capable of integrating architectural, structural, and MEP elements in the BIM analysis and modeling process (5).

The use of Revit allows for easier software integration and supports automatic clash detection, thereby helping to prevent potential conflicts between building elements. Overall, Revit accelerates workflow processes and enhances accuracy in both construction planning and execution (6). The name Revit, derived from 'revise instantly', highlights its ability to automatically update designs in real time. This function is crucial for complex construction projects, where modifications to one part influence the entire building system due to the high level of interconnectivity (7). Drawing sheets generated in BIM are not standalone entities; rather, they are integrated components of a synchronized system that ensures consistency across the entire model (8).

1.2. Quantity Take Off (QTO)

Quantity Take Off (QTO) is the process of measuring the volume or quantity of work as the basis for preparing the Bill of Quantities (BOQ) (9). This calculation encompasses various types of construction work, including preparatory work, substructure, superstructure, architectural, and MEP (Mechanical, Electrical, and Plumbing) components. In Indonesia, the QTO method is generally still performed manually based on AutoCAD drawings and supported by Microsoft Excel, with the Standard Method of Measurement (SMM) as the primary reference. The QTO process requires a high level of accuracy and consistency to ensure the reliability of project cost estimations (10).

Conventional QTO calculations are typically carried out manually by measuring the dimensions of each construction element, such as area, volume, length, and other unit measures. This process is prone to various errors, including misreading dimensions, inaccurate data input, arithmetic mistakes, rounding errors, and other forms of human error (11). Such inaccuracies can directly impact the accuracy of cost estimates and the execution of construction projects (12).

2. METHOD

The study titled "Quantity Take Off with Building Information Modeling on Superstructure Works" employs a non-experimental quantitative research design with a descriptive approach. Descriptive research aims to gather information based on actual conditions without testing hypotheses or drawing general conclusions. This study uses quantitative descriptive analysis, aligning with the research objective that requires numerical calculations to address the formulated problems. An intrinsic case study design is deemed most appropriate, as the data processing focuses on a specific data source that serves as the central focus of the research.

2.1. Research Object

This study adopts a case study approach focusing on the construction project of the Faculty of Law Building at Jenderal Achmad Yani University, located in Cimahi City, West Java. The building consists of three floors and functions as an educational facility under the management of Yayasan Kartika Eka Paksi. The digital modeling process was carried out using Autodesk Revit 2024 (student license) to generate integrated building information. This case study was selected due to its relevance as an academic facility and the availability of sufficient project data to support the Quantity Takeoff analysis.

2.2. Data Collection Technique

Data collection in this study was carried out through the documentation method, which relies on records of past events in the form of written materials, images, or other relevant documents. The data used in this research includes structural Detail Engineering Design (DED) drawings and the construction schedule (S-curve), obtained from the engineering staff of the project team. These materials are categorized as secondary data. In summary, the data utilized in this study consists of the building's structural DED, project schedule (S-curve), manpower data, unit price analysis (AHSP), and basic unit price information.

2.3. Research Stage

This research was carried out through several stages in accordance with the research framework. The process began with a literature review to examine relevant theories and previous studies related to Building Information Modeling (BIM), Quantity Take-Off (QTO), and project scheduling. The next step involved identifying the building as the object of study, including determining the types and scope of construction work to be analyzed.

Data were collected through documentation methods, specifically using Detailed Engineering Design (DED) drawings and the project implementation schedule provided by the engineering team. Based on these data, a 3D modeling process was conducted using Autodesk Revit software to accurately represent the structural elements. The final stage involved extracting output from the model in the form of work volume (QTO), which was then used for comparative analysis.

3. Results and Discussion

The DED (Detailed Engineering Design) drawings obtained were subsequently used to model both the structural elements and reinforcement components. The modeling process referred to the DED drawings and the standard details applied in the construction project. These standard details follow the provisions of SNI 2847:2019. This study specifically modeled the superstructure elements of the building, focusing on casting work, reinforcement work, and formwork. The modeling was carried out using Autodesk Revit 2024 with a student license. The result of the modeling process is presented in Figure 1.

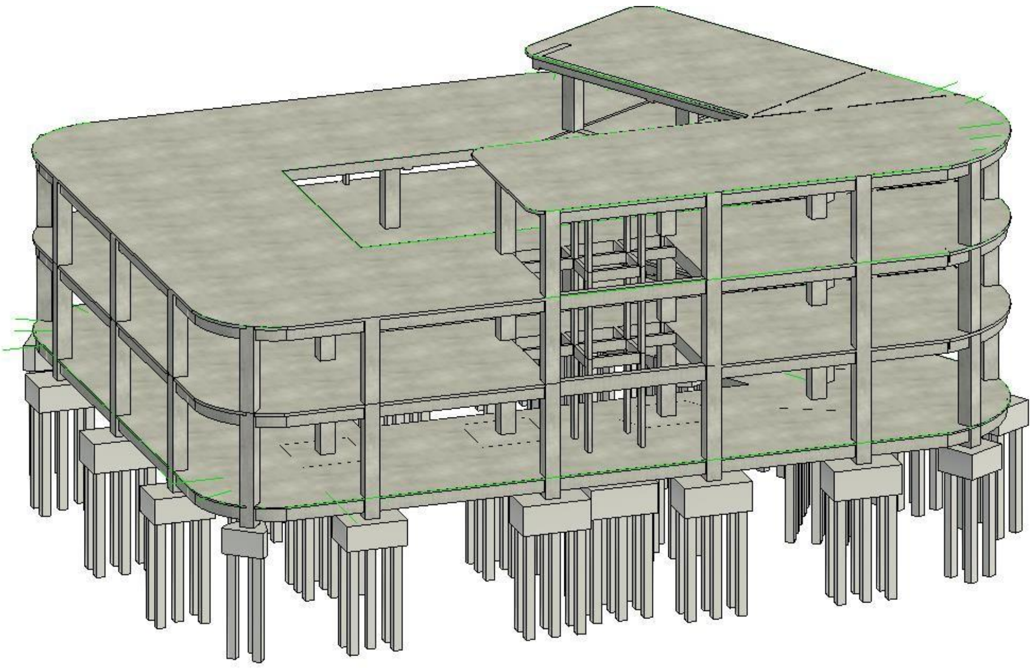

Figure 1. Revit Modeling Result

The data analysis results in this study indicate that the BIM method produces a smaller concrete volume compared to the conventional method. The volume of each type of work calculated using the BIM method is consistently lower than that of the conventional approach. Specifically, the BIM-based calculation for reinforcement work resulted in a volume that was 8.98% smaller than the conventional method. For casting work, the BIM method yielded a total volume that was 13.23% lower than the conventional QTO method. Similarly, the formwork calculation using BIM showed a volume difference of 8.57% less compared to the conventional method.

Tabel 1. Perbandingan Volume Pekerjaan

	Penulangan Besi				Beton				Bekisting				Rasio Besi		
	Elemen	Revit	Manual	Deviasi	Elemen	Revit	Manual		Elemen	Revit	Manual		Revit	Manual	
Lantai 1	S1	7643.78	7897.38	3.21%	S1	50.59	71.16	28.90%	S1	447.08	556.63	19.68%	151.09	110.99	-36.14%
	S2	441.29	481.24	8.30%	S2	0.81	3.12	74.04%	S2	10.69	26.10	59.04%	544.80	154.24	-253.21%
	S3	1036.39	1040.70	0.41%	S3	7.25	7.27	0.29%	S3	101.09	96.26	-5.02%	142.95	143.12	0.12%
	S4	264.12	317.90	16.92%	S4	1.41	1.71	17.49%	S4	22.39	27.26	17.86%	187.32	186.04	-0.69%
	K1	23527.83	24005.21	1.99%	K1	64.97	67.20	3.32%	K1	384.02	384.02	0.00%	362.13	357.20	-1.38%
	K2	623.96	694.76	10.19%	K2	1.86	1.89	1.48%	K2	28.32	28.32	0.00%	335.46	367.99	8.84%
	SOG	2421.70	2524.42	4.07%	SOG	65.00	65.00	0.00%	SOG	812.00	812.45	0.06%	37.26	38.84	4.07%
	Total Average			6.44%	Total Average			17.93%	Total Average			13.09%			
Lantai 2	B1	10344.00	10570.17	2.14%	B1	58.71	62.58	6.19%	B1	527.97	509.35	-3.66%	176.19	168.90	-4.31%
	B2	560.99	891.87	37.10%	B2	2.33	3.40	31.47%	B2	25.10	30.08	16.54%	240.77	262.33	8.22%
	B3	126.24	168.56	25.11%	B3	0.18	0.30	40.28%	B3	2.41	3.33	27.72%	701.33	559.24	-25.41%
	B4	2413.81	2571.26	6.12%	B4	13.21	13.30	0.69%	B4	191.27	188.70	-1.36%	182.73	193.31	5.47%
	B5	334.57	524.50	36.21%	B5	2.02	2.07	2.50%	B5	34.84	35.31	1.32%	165.63	253.17	34.58%
	K1	10146.34	11026.78	7.98%	K1	50.69	54.24	6.55%	K1	298.48	309.96	3.70%	200.16	203.28	1.53%
	K2	346.51	349.80	0.94%	K2	1.31	1.31	0.15%	K2	19.68	19.68	0.00%	264.51	266.62	0.79%
	S1	610.93	699.72	12.69%	S1	6.06	6.15	1.43%	S1	46.61	47.29	1.44%	100.81	113.82	11.42%
	SD1	3785.20	3973.15	4.73%	SD1	104.25	104.29	0.04%	SD1	721.56	719.27	-0.32%	36.31	38.10	4.69%
	Total Average			14.78%	Total Average			9.92%	Total Average			5.04%			
Lantai 3	B1	6460.00	7919.42	18.43%	B1	58.43	63.12	7.43%	B1	526.63	512.03	-2.85%	110.56	125.47	11.88%
	B2	610.11	747.82	18.41%	B2	2.51	3.38	25.68%	B2	24.69	29.96	17.60%	243.07	221.41	-9.78%
	B3	105.96	130.68	18.92%	B3	0.18	0.30	40.28%	B3	2.41	3.33	27.72%	588.67	433.56	-35.78%
	B4	2176.86	2243.98	2.99%	B4	13.69	13.75	0.43%	B4	194.62	195.96	0.68%	159.01	163.21	2.57%
	B5	329.91	333.89	1.19%	B5	2.25	2.26	0.38%	B5	34.79	33.88	-2.69%	146.63	147.83	0.82%
	K1	4557.86	4994.64	8.74%	K1	27.11	28.13	3.61%	K1	160.72	160.72	0.00%	168.12	177.58	5.33%
	K2	240.40	257.24	6.55%	K2	1.26	1.31	3.96%	K2	19.68	19.68	0.00%	190.79	196.07	2.69%
	S1	961.24	1111.84	13.55%	S1	9.53	9.77	2.44%	S1	73.30	75.14	2.46%	100.86	113.82	11.38%
	S2	7207.43	8546.92	15.67%	S2	72.67	74.27	2.15%	S2	484.50	570.27	15.04%	99.18	115.08	13.82%
	SD1	1091.88	1155.48	5.50%	SD1	30.47	30.33	-0.46%	SD1	210.12	209.18	-0.45%	35.83	38.10	5.93%
	Total Average			11.00%	Total Average			8.59%	Total Average			5.75%			
Lantai Atap	B1	2906.82	2913.65	0.23%	B1	23.72	27.05	12.31%	B1	216.33	219.38	1.39%	122.55	107.72	-13.77%
	B2	333.89	336.29	0.71%	B2	1.69	1.80	6.11%	B2	16.70	16.00	-4.38%	197.57	186.83	-5.75%
	B3	78.47	80.04	1.97%	B3	0.18	0.30	39.62%	B3	2.39	3.31	27.84%	435.94	268.51	-62.35%
	B4	826.71	865.34	4.46%	B4	5.26	5.26	0.05%	B4	71.60	75.18	4.76%	157.17	164.43	4.42%
	B5	333.78	334.69	0.27%	B5	1.34	2.25	40.41%	B5	22.52	33.73	33.24%	249.09	148.83	-67.36%
	S2	5174.89	6056.68	14.56%	S2	52.48	52.63	0.29%	S2	352.35	350.87	-0.42%	98.61	115.08	14.31%
	Total Average			3.70%	Total Average			16.46%	Total Average			10.41%			
	Grand Total Average			8.98%	Grand Total Average			13.23%	Grand Total Average			8.57%			

These results reflect the overall comparison, encompassing all types of structural work (reinforcement, formwork, and concrete) across all structural elements (columns, beams, and slabs). However, when the comparison is broken down by individual elements and work types across each floor level, the differences in quantities vary. These variations can be attributed to discrepancies between the automated calculations generated by the software and the manual conventional method. Overall, the differences in Quantity Takeoff (QTO) between the BIM and conventional methods are influenced by several factors.

A. Element Cutting

Calculations performed using Revit are automatically adjusted to account for overlapping elements. For instance, the volume of a beam is directly reduced when it intersects with a column, resulting in the software computing only the net length. Similarly, the height of the beam is automatically adjusted to accommodate the presence of a slab. Columns are also truncated by the slab thickness, ensuring that the slab volume is recorded based on its actual surface area.

Figure 2. Example of Overlapping Case

This is evident in beam B3 on the second floor, where the volume discrepancy reaches 40.28%. The intersection of elements significantly affects the calculation results, especially for smaller elements like B3, where minor cuts result in a relatively large volume difference in percentage terms. A similar case is observed in the ground floor sloof beam, which is intersected by the pile cap element, resulting in a substantial reduction in beam volume. This difference can be tested by comparing conventional calculations and the volume results from beam elements. An experimental calculation can be performed in Revit using the same dimensions and spacing as in the conventional method.

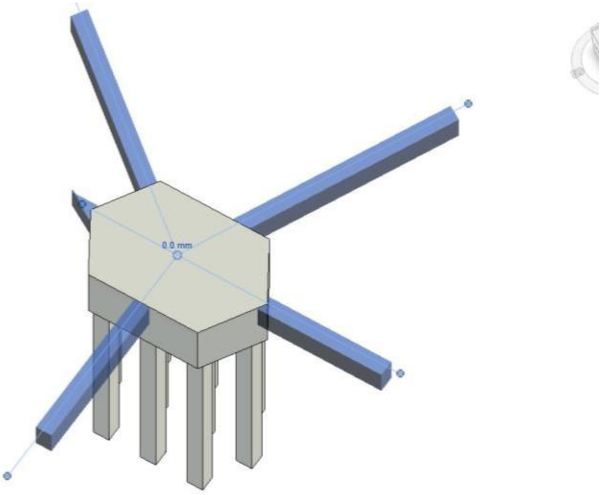

Figure 3. Example of an Intersection Case on a Sloof Beam

The modeling results using beam B1 yielded a volume that matches the conventional calculation based on the net length. This principle applies to all overlapping elements, such as columns and beams. While the conventional method calculates span length from one axis to another, Revit automatically subtracts the overlapping portions intersected by other elements.

B. Differences in Stirrup Calculation Result

The difference in reinforcement calculation results between the conventional method and the BIM method occurs due to varying levels of accuracy in calculating the quantity of reinforcement, particularly stirrups. For instance, in the beam located at axis D-B/10 on the second floor, the conventional method results in 89 stirrups with a total weight of 112.41 kg. In contrast, the BIM method, through modeling in Revit, calculates 82 stirrups with a total weight of 96.32 kg. Overall, the reinforcement weight of the beam on that axis is recorded at 359.72 kg using the conventional method, while the BIM method yields a total reinforcement volume of 312.53 kg.

<Lt 2 Rebar B 1>

A	B	C	D	E	F	G	H	I
Host Mark	Bar Diameter	Quantity By Rebar S	Bar Length	Area	Berat per m	Panjang Total	Berat	Maximum bar lengt
Lt 2 B1	10 mm	42	1951	70.88 mm²	0.56 kg/m	81960	45.60 kg	1951
Lt 2 B1	10 mm	2	8500	70.88 mm²	0.56 kg/m	17001	9.46 kg	8500
Lt 2 B1	10 mm	19	1951	70.88 mm²	0.56 kg/m	37073	20.63 kg	1951
Lt 2 B1	10 mm	19	1951	70.88 mm²	0.56 kg/m	37073	20.63 kg	1951
		82				173107	96.32 kg	
Lt 2 B1	19 mm	3	4249	283.53 mm²	2.23 kg/m	12748	28.37 kg	4249
Lt 2 B1	19 mm	3	4248	283.53 mm²	2.23 kg/m	12745	28.37 kg	4248
Lt 2 B1	19 mm	7	2123	283.53 mm²	2.23 kg/m	14863	33.08 kg	2123
Lt 2 B1	19 mm	2	2410	283.53 mm²	2.23 kg/m	4820	10.73 kg	2410
Lt 2 B1	19 mm	5	2123	283.53 mm²	2.23 kg/m	10617	23.63 kg	2123
Lt 2 B1	19 mm	2	5008	283.53 mm²	2.23 kg/m	10017	22.29 kg	5008
Lt 2 B1	19 mm	7	2123	283.53 mm²	2.23 kg/m	14863	33.08 kg	2123
Lt 2 B1	19 mm	2	2410	283.53 mm²	2.23 kg/m	4820	10.73 kg	2410
Lt 2 B1	19 mm	5	2123	283.53 mm²	2.23 kg/m	10617	23.63 kg	2123
		36				96110	213.91 kg	
		118				269217	310.23 kg	

Figure 4. Beam Output from Revit

The discrepancy in stirrup unit length calculations between the conventional method and the BIM-based method is attributed to the level of detail considered in representing the actual reinforcement shape. Revit calculates the stirrup length by accurately accounting for bends and the actual dimensions of the reinforcement, resulting in higher precision. Based on the case study shown in Figure 4, the stirrup length calculated using the conventional method is 2.05 meters, whereas Revit generates a length of 1.95 meters. This difference indicates that the BIM method can provide a more accurate estimation of reinforcement length and volume, which ultimately has a direct impact on the total rebar quantity calculations in the project.

The difference in volume between the BIM method and the conventional method has a direct impact on the cost required to complete the work. Cost estimation was conducted to determine the percentage difference between the two methods. The calculation was based on unit price data and standard work item cost analysis. The results indicate a cost difference of 5.42%, with the BIM method yielding a lower total cost of IDR 3,823,982,026.07 compared to the conventional method, which amounts to IDR 4,043,319,639.59.

4. Conclusions

The research conducted on the Faculty of Law Building project shows that Quantity Take-Off (QTO) calculations using the BIM method result in smaller structural work volumes compared to the conventional method, with differences of 13.23% for concrete, 8.98% for reinforcement, and 8.57% for formwork. The cost difference between the two methods amounts to IDR 217,825,853.73 or 5.42%, with the BIM method yielding a lower total cost.

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