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Comparative Analysis of Quantity Take Off Calculations for Structural Work Using BIM and Conventional Methods

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Abstract. Quantity Take Off (QTO) accuracy is essential for material estimation and project cost control, particularly for pilecap structures with complex reinforcement. This study compares reinforcement and concrete quantities, as well as processing time, between Building Information Modeling (BIM) and conventional QTO methods for three pilecap categories in the Solo-Yogyakarta-NYIA Kulon Progo Toll Road Project, Package 2.2B Trihanggo-Junction Sleman (STA 54+635 to STA 57+839). The BIM based method employed Autodesk Revit for three dimensional modeling and automatic quantity extraction, while the conventional method used AutoCAD and Microsoft Excel. The differences in reinforcement (0.677%) and concrete volume (0.014%) were minimal, indicating very high agreement between both methods. However, the BIM based method required substantially longer processing time because of the additional modeling process. The primary distinction between the methods therefore lies in the QTO preparation process rather than the resulting quantities.

Keywords: Autodesk Revit, building information modeling (BIM), conventional method, pilecap, quantity take off (QTO)

1. Introduction

Infrastructure development is a fundamental driver of a country's economic growth, as it improves mobility and logistics efficiency [1]. The Solo-Yogyakarta-NYIA Kulon Progo Toll Road Project, Package 2.2B Trihanggo-Junction Sleman (STA 54+635 to STA 57+839), is one of the sections of the Trans Java Toll Road currently under construction. To achieve the project's objectives, construction activities must be completed within the planned budget and schedule by improving the efficiency of the planning process. One of the key aspects supporting this objective is the implementation of an accurate Quantity Take Off (QTO), which plays an important role in minimizing the risk of cost overruns and

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project delays [2]. Therefore, a quantity estimation method capable of producing accurate material quantities is essential for effective construction project management [3].

With the advancement of construction technology, QTO methods can generally be classified into two approaches: the Building Information Modeling (BIM) based method and the conventional method [4]. Previous studies have reported that BIM based QTO provides higher effectiveness and efficiency than conventional quantity take-off methods [5][6][7]. The implementation of BIM reduces the potential for manual calculation errors by integrating three dimensional (3D) models with material quantity information, thereby enabling a more systematic identification and extraction of construction elements [8], [9]. Nevertheless, most previous studies have primarily focused on material volume estimation or overall cost estimation. Studies that simultaneously compare reinforcement quantities, concrete quantities, and the total processing time of QTO using identical technical parameters and calculation assumptions for pilecap structures remain limited. Therefore, further research is required to provide a more comprehensive evaluation of the differences in both quantity estimation results and total QTO processing time between BIM based and conventional methods.

2. **Methods**

2.1. Research design

This study employed a quantitative research method with a comparative case study approach to compare the results of Building Information Modeling (BIM) based Quantity Take Off (QTO) and the conventional QTO method using three pilecap structures of different dimensions from the Solo-Yogyakarta-NYIA Kulon Progo Toll Road Project, Package 2.2B Trihanggo-Junction Sleman (STA 54+635 to STA 57+839).

The research began with the collection of technical data and the project's detailed engineering design (DED) documents, which served as the basis for the QTO calculations. The BIM based QTO was then performed through three dimensional (3D) modeling followed by the automatic extraction of material quantities using Autodesk Revit. In contrast, the conventional method involved identifying construction elements from two dimensional drawings using AutoCAD and manually calculating material quantities using Microsoft Excel. The processing time for each method was measured using a stopwatch application on a mobile phone.

The comparison focused on three primary parameters: reinforcement quantities, concrete volumes, and total processing time. To ensure an objective comparison, several control variables were maintained, including the same technical data, identical pilecap specimens, and consistent calculation assumptions for both QTO methods. Consequently, any differences observed in the results can be attributed to the calculation method rather than to variations in the input data or calculation assumptions.

2.2. Research objects and data

The research object of this study was the pilecap structural work in Zone B of the Elevated Main Road section of the Solo-Yogyakarta-NYIA Kulon Progo Toll Road Project, Package 2.2B Trihanggo-Junction Sleman (STA 54+635 to STA 57+839), located in Mlati and Gamping Districts, Sleman Regency, Special Region of Yogyakarta, Indonesia. The research location is shown in Figure 1.

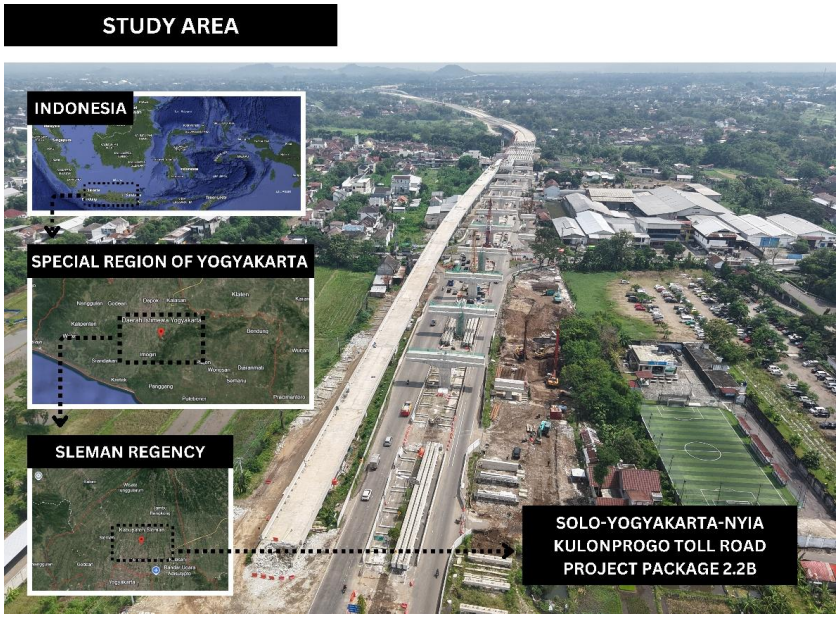


Figure 1. Research location

This study focused on three pilecap categories with different dimensions, selected using a purposive sampling approach. The selected specimens consisted of a small pilecap (P54A), a medium pilecap (P44), and a large pilecap (P64).

The data used in this study consisted of both primary and secondary data. The primary data included the pilecap modeling results, the results of BIM based and conventional QTO calculations, and the processing time required to complete the QTO for each method. The secondary data were obtained from the project planning documents, including the project technical data and the Detailed Engineering Design (DED) documents.

2.3. Research procedure

This study was conducted through a series of systematic stages to compare the results of Building Information Modeling (BIM)-based Quantity Take Off (QTO) and the conventional QTO method. The overall research methodology is illustrated in Figure 2.

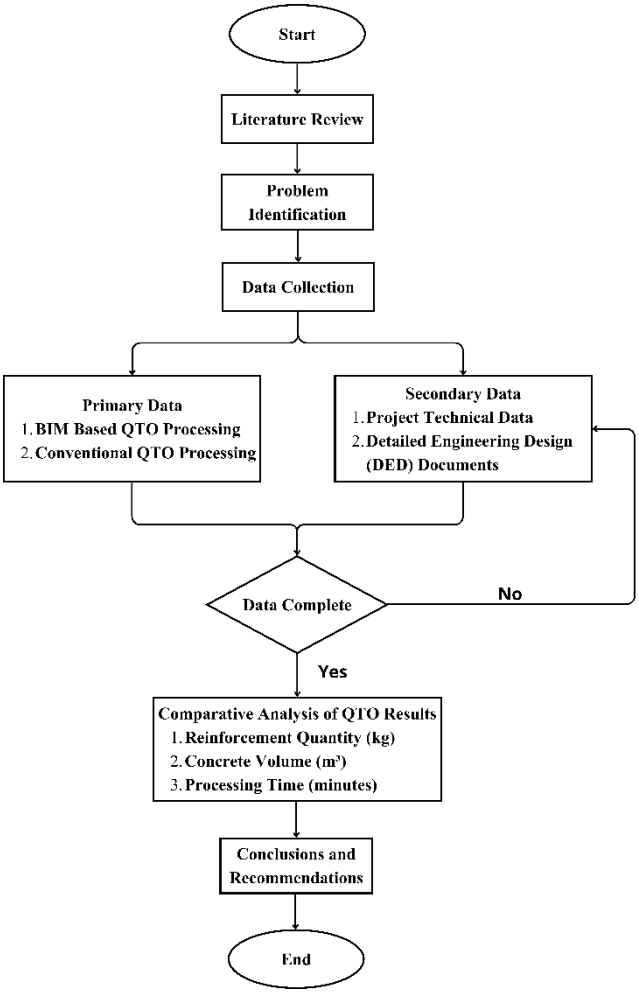


Figure 2. Research procedure

2.4. Data analysis

A comparative analysis of the Quantity Take Off (QTO) results and processing time was conducted to evaluate the differences between the Building Information Modeling (BIM) based method and the conventional method. The comparison was performed using three primary parameters: reinforcement quantity (kg), concrete volume (m³), and processing time (minutes) for three pilecap categories, namely the small pilecap (P54A), medium pilecap (P44), and large pilecap (P64).

The difference between the results obtained from the two methods was calculated using the difference value, as expressed in Equation (1).

$$\Delta = Q_{BIM} - Q_{CON} \quad (1)$$

where:

Δ = difference between the BIM based and conventional QTO results
Q_{BIM} = QTO result obtained using the BIM based method
Q_{CON} = QTO result obtained using the conventional method

The relative difference between the two methods was subsequently calculated using the percentage difference, as presented in Equation (2).

$$P = \frac{Q_{BIM} - Q_{CON}}{Q_{CON}} \times 100\% \quad (2)$$

where:

P = percentage difference (%)

Q_{BIM} = QTO result obtained using the BIM based method
Q_{CON} = QTO result obtained using the conventional method

The conventional method was used as the reference value in the percentage difference calculation because it represents the approach most commonly applied in QTO preparation within construction practice. The analysis results were then interpreted based on the magnitude and direction of the calculated differences. A positive value indicates that the BIM based method produced a higher QTO result than the conventional method, whereas a negative value indicates that the BIM based result was lower. Accordingly, a smaller percentage difference indicates a higher level of agreement between the QTO results obtained using the two methods.

3. Results and Discussion

3.1. Comparison of reinforcement quantity take off (QTO)

A summary of the reinforcement Quantity Take Off (QTO) analysis is presented in Table 1 and Figure 3.

Table 1. Comparison of Reinforcement Quantity Take Off Results

No	Method		Difference (kg)	Percentage (%)
	BIM based (kg)	Conventional (kg)		
Small pilecap (P54A): 11.00 × 6.90 × 2.50 m				
1	26806.208	26869.749	**-63.541**	**-0.236**
Medium pilecap (P44): 20.50 × 8.00 × 3.00 m				
2	81038.940	81179.515	**-140.575**	**-0.173**
Large pilecap (P64): 17.50 × 14.50 × 3.00 m				
3	117487.280	118818.260	**-1330.980**	**-1.120**
Total reinforcement quantity				
4	225332.428	226867.524	**-1535.096**	**-0.677**

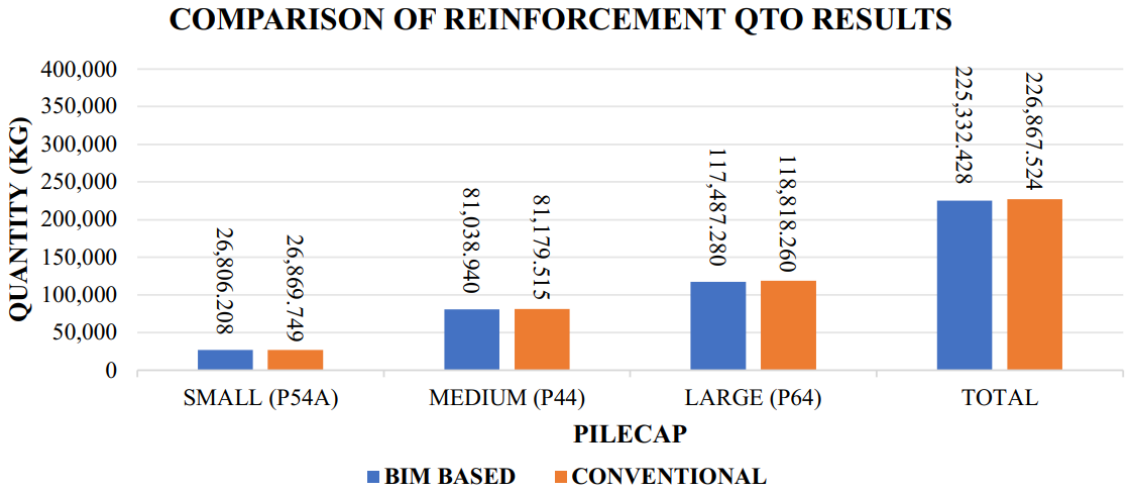


Figure 3. Comparison of Reinforcement Quantity Take Off Results

Based on the results, the BIM based QTO produced a total reinforcement quantity that was 1,535.096 kg (0.677%) lower than that obtained using the conventional method. This result indicates a very high level of agreement between the two methods in estimating reinforcement quantities. However, the

percentage differences did not exhibit a fully linear trend across the three pilecap size categories. The small pilecap (P54A) showed a difference of 0.236%, the medium pilecap (P44) showed a difference of 0.173%, and the large pilecap (P64) exhibited the highest difference at 1.120%. These variations indicate that the magnitude of the percentage difference is influenced not only by the pilecap dimensions but also by the complexity of the reinforcement configuration.

The differences in reinforcement quantities can also be attributed to the capability of the BIM based method to identify reinforcement elements in greater detail through three dimensional (3D) visualization. This enables each reinforcing bar to be modeled according to its actual position within the structure, thereby reducing the potential for interpretation errors compared with the conventional method, which relies on the interpretation of two dimensional (2D) construction drawings.

Using identical calculation parameters and assumptions, the findings indicate that the BIM based QTO method produces slightly lower reinforcement quantities while providing a more detailed representation of the structural elements.

3.2. Comparison of concrete quantity take off (QTO)

A summary of the concrete Quantity Take Off (QTO) analysis is presented in Table 2 and Figure 4.

Table 2. Comparison of Concrete Quantity Take Off Results

No	Method		Difference (m^3)	Percentage (%)
	BIM based (m^3)	Conventional (m^3)		
Small pilecap (P54A): 11.00 × 6.90 × 2.50 m				
1	186.335	186.327	**0.008**	**0.004**
Medium pilecap (P44): 20.50 × 8.00 × 3.00 m				
2	481.677	481.659	**0.018**	**0.004**
Large pilecap (P64): 17.50 × 14.50 × 3.00 m				
3	746.283	746.114	**0.170**	**0.023**
Total concrete quantity				
4	1414.295	1414.100	**0.196**	**0.014**

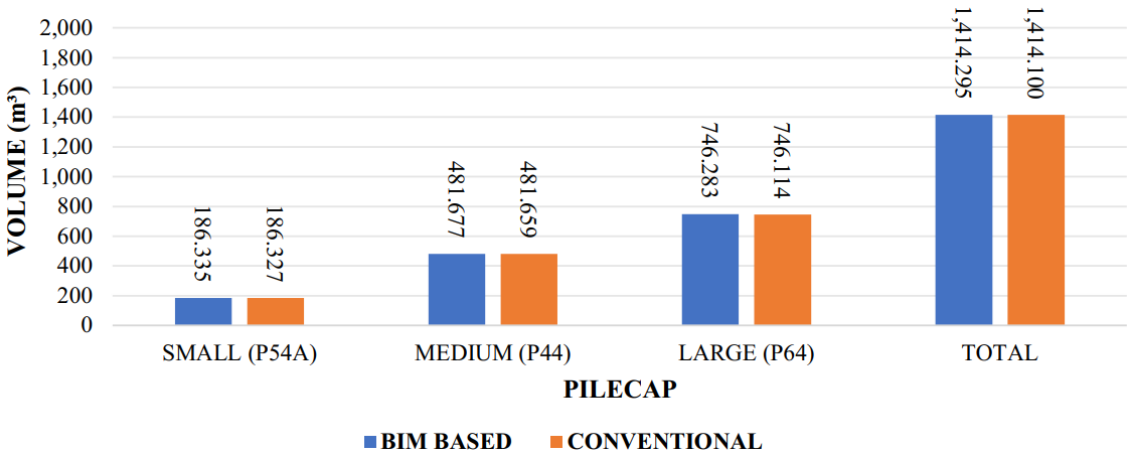


Figure 4. Comparison of Concrete Quantity Take Off Results

Based on the results, the BIM based method produced a total concrete volume that was 0.196 m^3 (0.014%) higher than that obtained using the conventional QTO method. When the results were analyzed by pilecap category, the small pilecap (P54A) showed a difference of 0.008 m^3 (0.004%), the medium pilecap (P44) showed a difference of 0.018 m^3 (0.004%), and the large pilecap (P64) exhibited the largest

difference of 0.170 m³ (0.023%). These results indicate a very high level of agreement between the two methods. This high level of consistency can be attributed to the fact that both methods employed identical pilecap geometric data, with the observed differences primarily resulting from the reinforcement volume incorporated within each pilecap model.

In the BIM based method, concrete volume was calculated automatically from the three dimensional (3D) model, whereas the conventional method relied on manual geometric calculations based on the dimensions of the pilecap structure. These findings indicate that the implementation of BIM does not produce a significant difference in the calculated concrete volume. Instead, its primary advantage lies in the automation of the quantity extraction process.

3.3. Comparison of quantity take off (QTO) processing time

A summary of the QTO processing time analysis is presented in Table 3 and Figure 5.

Table 3. Comparison of Quantity Take Off Processing Time

No	Method		Difference (minutes)	Percentage (%)
	BIM based (minutes)	Conventional (minutes)		
Small pilecap (P54A): 11.00 × 6.90 × 2.50 m				
1	82.739	23.636	**59.104**	**250.062**
Medium pilecap (P44): 20.50 × 8.00 × 3.00 m				
2	129.747	58.334	**71.413**	**122.421**
Large pilecap (P64): 17.50 × 14.50 × 3.00 m				
3	194.902	33.582	**161.319**	**480.372**
Total processing time				
4	407.387	115.552	**291.836**	**252.559**

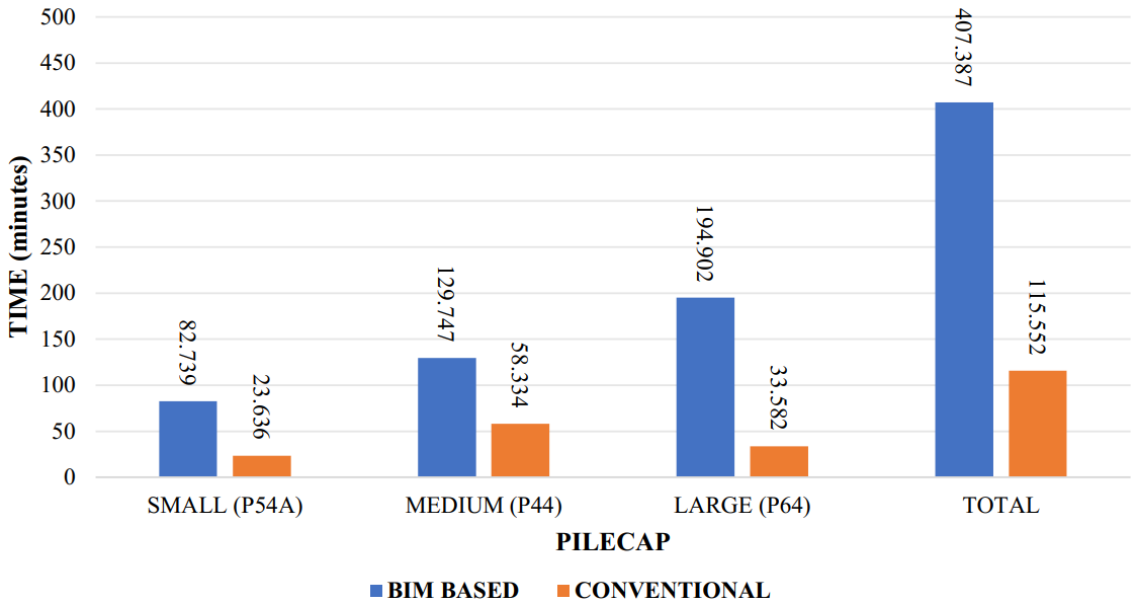


Figure 5. Comparison of Quantity Take Off Processing Time

Based on the results, the BIM based method required an additional 291.836 minutes of processing time, representing an increase of 252.559% compared with the conventional method. Specifically, the

processing time differences were 59.104 minutes (250.062%) for the small pilecap (P54A), 71.413 minutes (122.421%) for the medium pilecap (P44), and 161.319 minutes (480.372%) for the large pilecap (P64).

These differences were primarily influenced by the scope of work included in each method. The processing time for the BIM based method encompassed the entire workflow, including three dimensional (3D) modeling and the subsequent automatic extraction of QTO data. In contrast, the processing time for the conventional method included only the interpretation of two dimensional construction drawings and the manual calculation of material quantities, without accounting for the time required to produce the drawings.

Therefore, the longer processing time of the BIM based method should not be interpreted as evidence of lower efficiency. Rather, it reflects the additional effort required to complete the three dimensional (3D) model before material quantities can be extracted automatically.

4. Conclusion

This study aimed to compare the results of Building Information Modeling (BIM) based and conventional Quantity Take Off (QTO) methods for pilecap structures in terms of reinforcement quantity, concrete volume, and processing time. The findings demonstrated that both methods achieved a very high level of agreement when identical technical data, calculation parameters, and assumptions were applied.

The results also indicate that the primary difference between the BIM based and conventional QTO methods lies not in the resulting material quantities but in the QTO preparation process. Therefore, the evaluation of BIM implementation for QTO should not be based solely on the resulting material quantities. It should also consider the accuracy of element identification, the complexity of the structural components being analyzed, and the scope of work included in the comparison.

Future studies are recommended to evaluate the application of BIM based and conventional QTO methods using a broader range of structural objects, equivalent preparation procedures, and a wider analytical scope by incorporating cost estimation and actual construction quantities. Such an approach would enable a more comprehensive assessment of the performance and applicability of both methods.

Declaration of AI and AI assisted technologies in the writing process

During the preparation of this work the author(s) used google translate in order to translate from Indonesian to English. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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