

COMPONENT-LEVEL ANALYSIS OF QUANTITY TAKE-OFF DEVIATIONS BETWEEN BIM AND CONVENTIONAL METHODS IN REINFORCED CONCRETE BRIDGE STRUCTURES

Indra Kusuma^{1*}, Dedi Enda²

^{1,2}Department of Civil Engineering, State Polytechnic of Bengkalis, Riau, Indonesia

E-mail: kesumaindra976@gmail.com^{1*}, dediendra05@gmail.com²

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Abstract

Material quantity calculation is a critical stage in construction planning because the accuracy of quantity estimation directly affects project cost control and decision-making. In bridge construction, Quantity Take-Off (QTO) is commonly performed using conventional methods based on two-dimensional drawings, which may lead to quantity deviations due to geometric simplifications and limitations in representing complex structural details. This study aims to compare concrete and reinforcement quantities obtained using conventional methods and Building Information Modeling (BIM) through Autodesk Revit, as well as to identify the factors causing quantity deviations in bridge components. The research was conducted on the Tanjung Alai Village Bridge by developing a three-dimensional BIM model based on Detail Engineering Design (DED) drawings. Quantity comparisons were evaluated using percentage error and Root Mean Square Error (RMSE) analyses. The results showed average error values of 0.157% for concrete and 1.559% for reinforcement, with RMSE values of 0.015 m³ and 0.009 m³, respectively. The largest concrete deviation occurred in the Backwall due to its non-prismatic geometry, while the largest reinforcement deviation was found in the wing wall because BIM captured actual reinforcement length variations not fully represented in conventional calculations. These findings indicate that BIM provides reliable quantity estimation and a more detailed representation of structural geometry and reinforcement configurations in reinforced concrete bridge structures.

Keywords: *Autodesk Revit; Building Information Modeling (BIM); Quantity Deviation Analysis; Quantity Take-Off (QTO); Reinforced Concrete Bridge.*

INTRODUCTION

Accurate material quantity estimation is a fundamental aspect of construction project planning because it directly influences cost control, resource allocation, and decision-making throughout the project lifecycle. In bridge construction projects, the Quantity Take-Off (QTO) process serves as the basis for cost estimation, material procurement planning, and project scheduling. Inaccurate quantity calculations may lead to material waste and unreliable cost estimates, which can ultimately reduce construction efficiency and affect overall project performance (Atmajaya & Abma, 2025; Pratama et al., 2025). Therefore, reliable quantity estimation methods are essential to support effective planning and successful implementation of bridge construction projects. Although conventional Quantity Take-Off (QTO) methods based on two-dimensional (2D) drawings are still widely applied in construction projects, they have several limitations that may reduce the accuracy of quantity estimation. In this approach, quantity calculations are performed manually by interpreting engineering drawings, making the results highly dependent on the estimator's experience, judgment, and attention to detail. In reinforced concrete bridge construction, structural elements often contain complex geometries and varying reinforcement arrangements that may require assumptions and geometric simplifications during the calculation process. These conditions increase the possibility of calculation errors, inconsistencies in quantity data, and differences between estimated quantities and actual project requirements (Stefanus Lutfiansyah, 2025). As the complexity of structural components increases, the risk of quantity deviations also becomes greater, which may affect the reliability of cost estimation and material planning (Pratama et al., 2025; Sadad et al., 2022). The advancement of digital technology in the construction industry has encouraged the adoption of Building Information Modeling (BIM) as a more integrated approach to project planning and management. BIM enables the development of three-dimensional models that not only represent structural geometry visually but also store technical information that can be utilized for analysis and

decision-making processes. In Quantity Take-Off (QTO) applications, BIM can automatically generate concrete volumes and reinforcement quantities based on the developed model, thereby reducing dependence on manual calculations and minimizing errors associated with drawing interpretation (Nafiyah & Martina, 2022). One of the most widely used BIM software applications is Autodesk Revit, which provides integrated structural modeling and quantity extraction capabilities. These features enable BIM to improve the accuracy, consistency, and efficiency of quantity estimation processes in construction projects (Reza et al., 2024).

Numerous studies have demonstrated that BIM can provide accurate and consistent quantity estimations compared with conventional methods. In both building and infrastructure projects, BIM has been widely adopted to automate Quantity Take-Off processes, thereby reducing errors associated with manual calculations and drawing interpretation. Previous studies have reported relatively small quantity deviations between BIM-based and conventional estimation approaches. (Setiawan et al., 2022) reported deviations of 0.14% for concrete, 0.49% for reinforcement, and 0.07% for formwork using Autodesk Revit. Similarly, (Adha, 2023) identified a reinforcement quantity difference of 4.04% in bridge structures, while (Asih et al., 2022) reported efficiency improvements of 1.67% for concrete and 3.32% for reinforcement. (Farizah, 2024) also observed minimal deviations of 0.021% for concrete and 1.183% for reinforcement. Collectively, these findings indicate that BIM is capable of producing reliable quantity information and contributes to more effective construction planning processes.

Although numerous studies have confirmed that BIM can generate accurate quantity estimations with relatively small deviations compared to conventional methods, most of these studies have primarily focused on comparing quantity results and evaluating estimation accuracy. Limited attention has been given to investigating the causes of quantity deviations at the individual structural component level, particularly in reinforced concrete bridge structures. In practice, each structural component possesses unique geometric characteristics and reinforcement configurations that may result in different levels of quantity deviation. Consequently, existing studies generally provide information regarding the magnitude of quantity differences without offering detailed explanations of the factors responsible for such deviations. Therefore, further research is required not only to compare Quantity Take-Off results obtained from BIM and conventional methods but also to identify the factors contributing to quantity deviations within individual reinforced concrete bridge components.

Based on the identified research gap, this study aims to compare concrete and reinforcement quantities obtained using conventional methods and Building Information Modeling (BIM) through Autodesk Revit in reinforced concrete bridge structures. In addition to evaluating the magnitude of quantity deviations between the two approaches, this study also investigates the factors influencing quantity deviations across individual structural components. The novelty of this research lies in its component-level analysis of quantity deviations, which extends beyond comparing calculation results by examining the influence of structural geometry and reinforcement configurations on quantity estimation outcomes. Therefore, this study is expected to provide a more comprehensive understanding of BIM implementation in Quantity Take-Off processes and serve as a reference for improving quantity estimation accuracy in reinforced concrete bridge construction projects.

METHOD

This study aims to analyze and compare the results of Quantity Take Off (QTO) calculations for concrete and reinforcement works, comparing conventional methods with approaches based on Building Information Modeling (BIM) using Autodesk Revit software. The BIM method enables an integrated calculation process through three-dimensional modeling, which has proven capable of presenting material quantity data with a level of accuracy and efficiency far superior to conventional methods that rely solely on two-dimensional drawings (Pratama et al., 2025). Furthermore, the implementation of BIM supports the integration of all project data and has the potential to minimize calculation errors from the early stages of planning (Purwanto et al., 2025). All calculation results obtained from both methods were subsequently used as the basis for comparison to evaluate the level of agreement, deviation patterns, and reliability of quantity estimation results generated by each approach.

The research procedure was arranged systematically and sequentially, following the research workflow illustrated in the flow diagram shown in Figure 1.

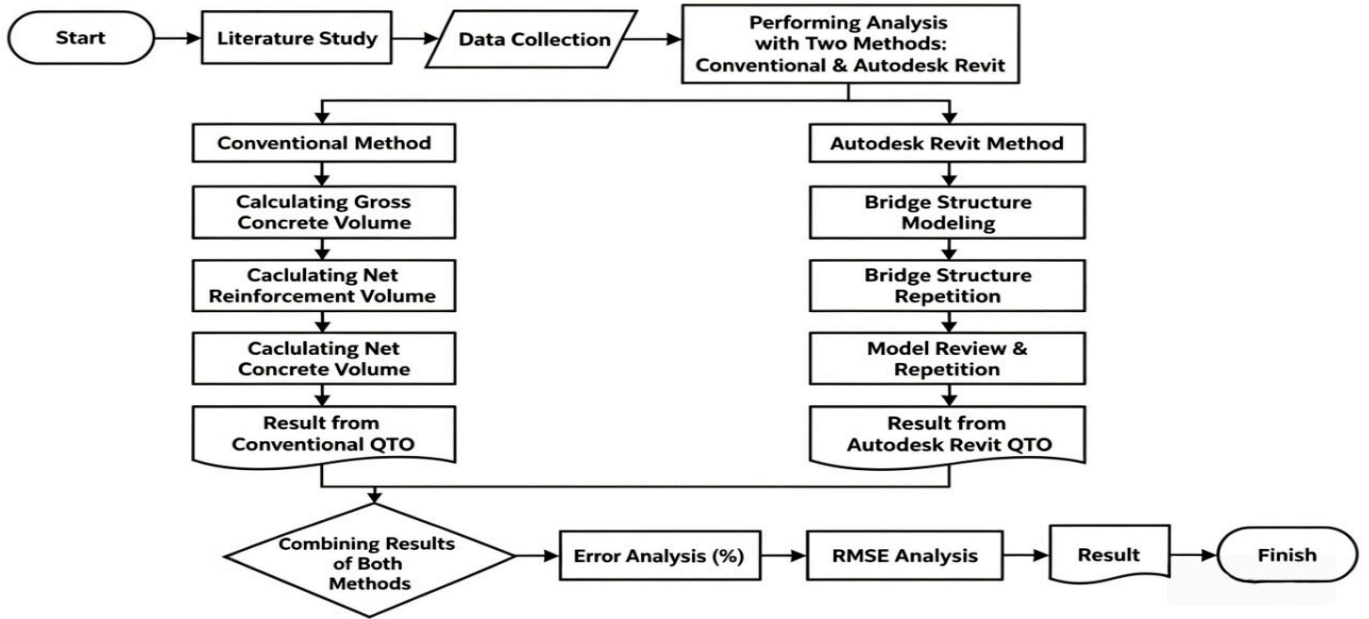


Figure 1. Research Methodology Flowchart

The research process began with a literature study to gain a comprehensive understanding of the basic concepts of Quantity Take Off (QTO), the principles of conventional methods, and the application of Building Information Modeling (BIM) in quantity calculations for construction works. The next step involved data collection, including technical working drawings or Detail Engineering Design (DED) documents and other planning documents for the Tanjung Alai Village Bridge project, which served as the main reference basis for all analysis processes.

Quantity calculation analysis was carried out using two approaches: the conventional method and the BIM-based method assisted by Autodesk Revit. A detailed explanation of each method is as follows:

Conventional Method

In the conventional method, calculations were carried out in stages, starting from determining concrete volume, reinforcement volume, and finally obtaining the net concrete volume. The detailed steps are described below.

- a. Calculation of gross concrete volume

This calculation was performed by breaking down each structural component into simpler geometric shapes to facilitate calculation based on length, cross-sectional area, and the number of existing elements.

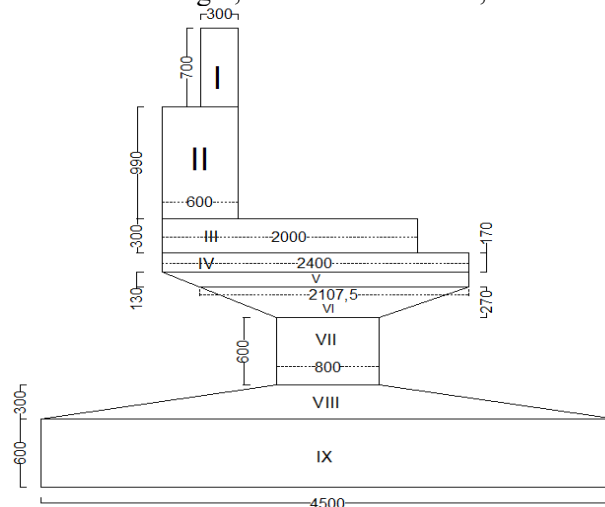


Figure 2. Abutment component elements categorized into several components

The formula used is:

$$V(K_i) = n \times (A \times L) \quad (1)$$

Where:

V_{K_i} = Gross concrete volume of the i-th component (m^3)

n = Number of elements in the i-th component

A = Cross-sectional area of the component (m^2)

L = Length of the component (m)

b. Calculation of reinforcement volume

The reinforcement quantities used in the conventional method were obtained directly from the Bar Bending Schedule (BBS) provided in the Detail Engineering Design (DED) documents. Therefore, no recalculation of reinforcement detailing was performed in this study. The reinforcement quantities, initially expressed in weight units, were converted into volume units using the density of steel to enable direct comparison with the BIM-generated quantity results. The formula used is:

$$V_{T,i} = \frac{W_{T,i}}{\rho \text{ baja}} \quad (2)$$

Where:

$V_{T,i}$ = Reinforcement volume of the i-th component (m^3)

$W_{T,i}$ = Reinforcement weight of the i-th component (kg)

ρ = Density of steel reinforcement (7850 kg/m^3)

c. Calculation of net concrete volume

This value was obtained by subtracting the gross concrete volume by the volume of reinforcement contained within it, to determine the actual volume value of the concrete itself. The formula used is:

$$V_{B,i} = V_{K,i} - V_{T,i} \quad (3)$$

Where:

$V_{B,i}$ = Net concrete volume of the i-th component (m^3)

$V_{K,i}$ = Gross concrete volume of the i-th component (m^3)

$V_{T,i}$ = Reinforcement volume of the i-th component (m^3)

Accordingly, the net concrete volume used in this study was determined by subtracting the reinforcement volume from the gross concrete volume for each structural component. The resulting net concrete volume was subsequently used as the basis for comparison with the BIM-generated quantity results.

Based on the equations above, calculations were performed by breaking down structural elements into simple geometric shapes, allowing the volume value of each part to be determined systematically and gradually.

BIM-Based Method (Autodesk Revit)

Calculations using the BIM approach were carried out through three-dimensional modeling of the bridge structure within Autodesk Revit software. This process began with the creation of models for each structural element using the Family feature, fully adapted to the Detail Engineering Design (DED) drawings, including abutments, wing walls, base slabs, foundation piles, and other bridge components.

The structural elements were modeled according to the geometric dimensions specified in the DED drawings. Meanwhile, reinforcement modeling was performed using the Rebar tool, where the placement and shape of the reinforcement were adjusted to the reinforcement details shown in the design drawings. Through this approach, the BIM model was able to represent both the structural geometry and reinforcement configuration in a three-dimensional environment.

Once all structural elements and reinforcement had been fully modeled, Quantity Take-Off (QTO) data were automatically generated using the Schedule feature available in Autodesk Revit. This feature directly provides detailed information on concrete and reinforcement quantities based on the attributes and dimensions defined within the model. The resulting quantity schedules for concrete and reinforcement are presented in Figures 3 and 4, respectively.

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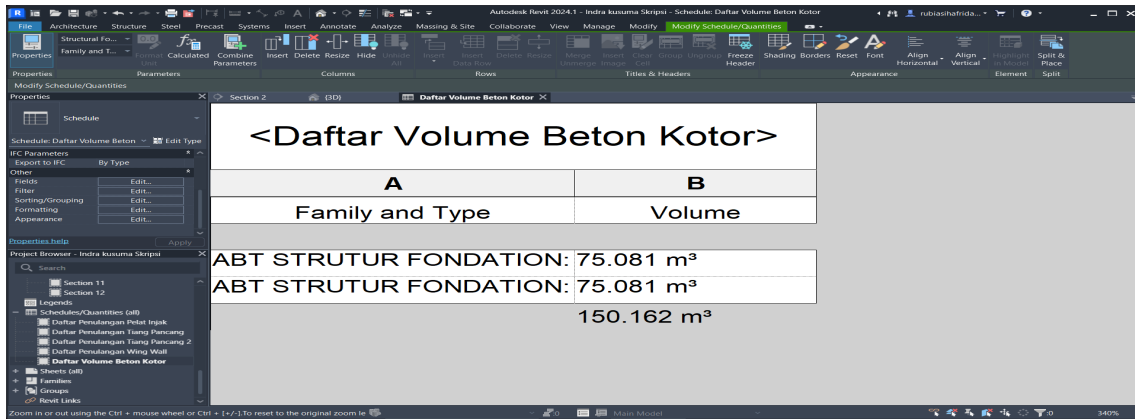


Figure 3. Concrete Volume Schedule

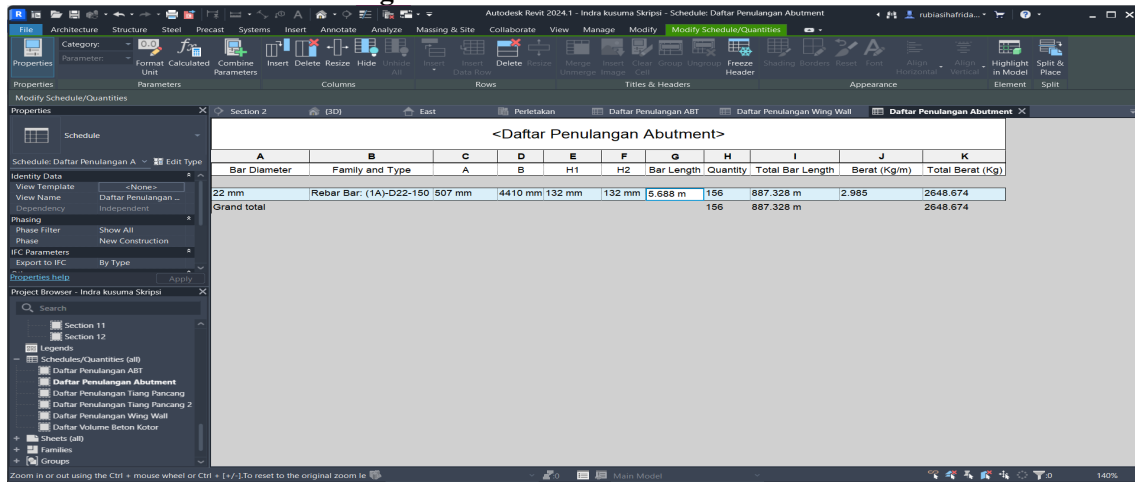


Figure 4. Reinforcement Volume Schedule

Data Testing and Analysis

Once all calculation results from both methods were obtained, the next step involved testing and analysis using the percentage of error (Error) and the statistical method Root Mean Square Error (RMSE). The formulas applied are as follows:

- a. Percentage of Error

$$\text{Error (\%)} = \frac{|V.k - V.r|}{V.k} \times 100\% \quad (4)$$

Where:

Error (%) = Percentage difference between conventional and BIM-based quantity results (%)

V_k = Quantity value obtained from the conventional method (m³)

V_r = Quantity value obtained from the BIM-based method (m³)

- b. Root Mean Square Error (RMSE)

$$\text{RMSE} = \sqrt{\frac{\sum (V_k - V_r)^2}{n}} \quad (5)$$

Where:

V_k = QTO value from conventional method

V_r = QTO value from BIM method

n = Number of data points compared

In this study, RMSE was calculated using the differences between the conventional and BIM-based quantity results for each bridge component. The resulting RMSE values are expressed in cubic meters (m³) and represent the average magnitude of deviation between the two methods.

Calculation of error values and RMSE was performed to determine the magnitude of differences between the two methods for each structural component, as well as to measure the average level of deviation comprehensively. The results of this analysis were subsequently used to assess the level of accuracy and reliability of BIM implementation compared to conventional methods.

RESULTS AND DISCUSSION

Implementation of BIM Modeling

The application of the Building Information Modeling (BIM) method in this research was carried out using Autodesk Revit software, through a three-dimensional modeling process of the entire bridge structure based on available Detail Engineering Design (DED) drawings. Modeling was conducted systematically by forming each structural component, including abutments, wing walls, base slabs, floor structures, sidewalks, culverts, and foundation piles, all integrated within a single model. The complete visualization of the three-dimensional model generated in this study is presented in Figure 5.

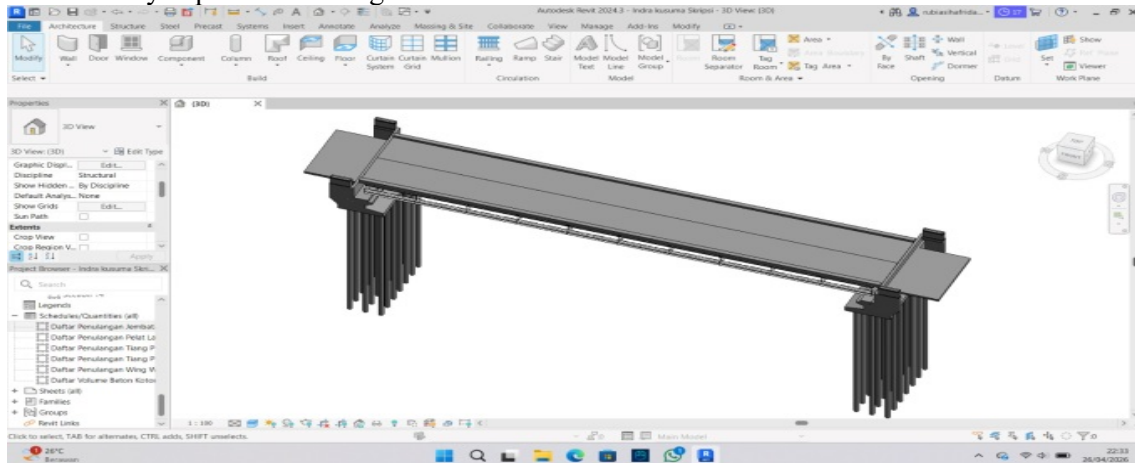


Figure 5. 3D Bridge Modeling Results

Once the modeling process was fully completed, data regarding Quantity Take-Off (QTO) were extracted automatically using the scheduling feature available in Autodesk Revit. This feature enables the software to calculate and display material quantities directly based on the geometric properties and attributes defined within the model. The resulting quantity data include detailed concrete and reinforcement quantities for each structural component and were subsequently used as the basis for comparison with the conventional calculation results presented in Table 1. This automation process significantly reduces the potential for human error commonly associated with manual quantity calculations.

Calculation Results

Based on the analysis that has been conducted, the values of Quantity Take Off (QTO) for concrete and reinforcement works were successfully obtained using both conventional calculation methods and BIM-based methods. The complete calculation results, covering gross concrete volume, reinforcement volume, and net concrete volume, are presented in Table 1.

Table 1. Recapitulation of Concrete and Reinforcement Volume Calculation Results

No	Structural Component	Gross Concrete Volume			Reinforcement Volume			Net Concrete Volume		
		(M) (m3)	(R) (m3)	(Δ) (m3)	(M) (m3)	(R) (m3)	(Δ) (m3)	(M) (m3)	(R) (m3)	(Δ) (m3)
1	Abutment	150,162	150,162	0,000	2,145	2,130	0,015	148,017	148,032	0,015
2	Wing wall	11,139	11,139	0,000	0,213	0,198	0,015	10,926	10,941	0,015
3	Base Slab	24,560	24,560	0,000	0,615	0,618	0,003	23,945	23,942	0,003
4	Deck and Sidewalk	131,199	131,199	0,001	3,189	3,192	0,003	128,009	128,007	0,003
5	Backwall	3,741	3,712	0,029	0,034	0,034	0,000	3,707	3,678	0,029
6	Bored Pile	140,137	140,134	0,003	2,637	2,637	0,001	137,501	137,497	0,004

* Note :

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(M) = Manual / Conventional Method

(R) = BIM / Autodesk Revit Method

(Δ) = Difference

Source: Result of research calculations, 2026

Table 1 presents the quantity take-off results obtained using the conventional method and BIM for each reinforced concrete bridge component. To facilitate a clearer comparison of quantity distributions and identify the components contributing most significantly to the observed deviations, the concrete and reinforcement quantities obtained from both methods are further illustrated in graphical form, as shown in Figures 6 and 7. These visualizations provide an overview of quantity variations among structural components and serve as a basis for the subsequent analysis of deviation patterns.

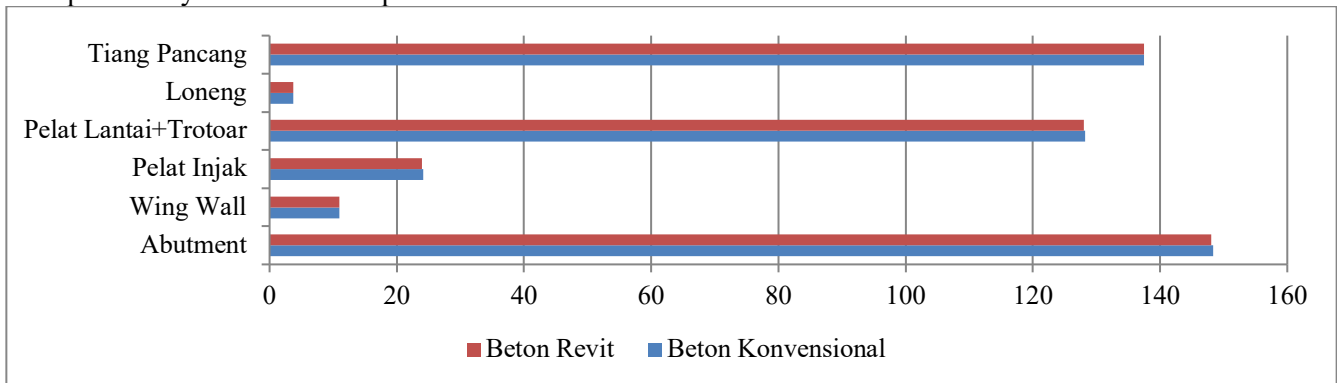


Figure 6. Comparison of Concrete Quantities Obtained from BIM and Conventional Methods

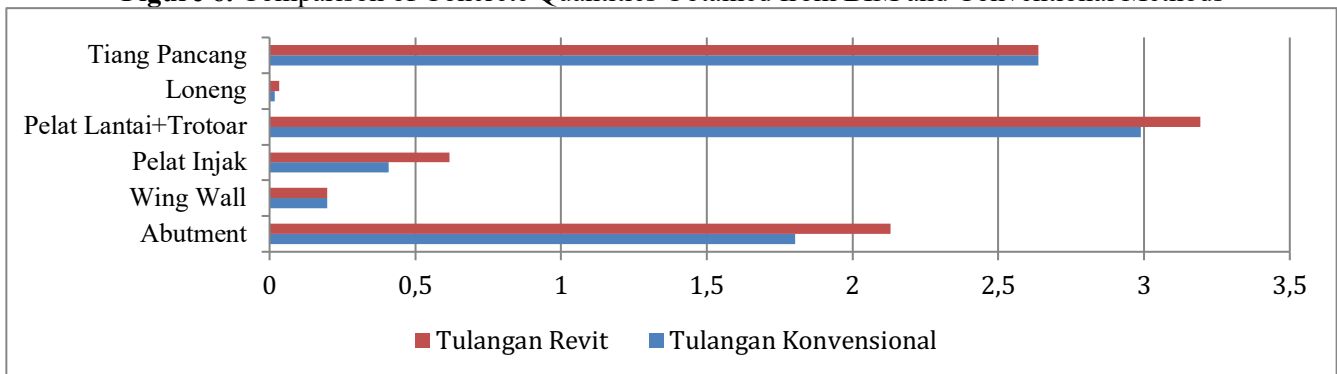


Figure 7. Comparison of Reinforcement Quantities Obtained from BIM and Conventional Methods

Figures 6 and 7 show that the quantity differences between the conventional method and BIM are generally small across all bridge components, indicating a high level of consistency between the two approaches. Nevertheless, the magnitude of deviation varies among structural elements. For concrete quantities, the most noticeable difference can be observed in the Backwall component, whereas reinforcement quantity differences are more evident in the Wing Wall and Abutment components. These observations suggest that component geometry and reinforcement configuration play an important role in influencing quantity estimation results and therefore warrant further investigation at the component level.

Based on Table 1, the quantity take-off results generated using the conventional method and BIM exhibit relatively small differences across all bridge components. Nevertheless, the magnitude of deviation varies according to the geometric characteristics and reinforcement detailing of each component. The highest deviation in net concrete volume was observed in the Backwall component, with a difference of 0.029 m³. This deviation is associated with the geometric configuration of the Beckwall, which contains inclined surfaces and a tapered cross-section. In conventional calculations, the volume was determined using simplified geometric assumptions, whereas BIM calculated the volume directly from the three-dimensional model, resulting in a more detailed representation of the actual structure.

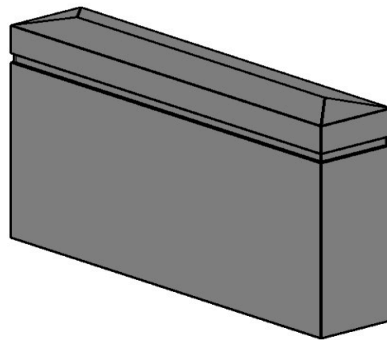


Figure 8. Geometry of the Backwall Component in the BIM Model

Figure 8 shows the geometric configuration of the Backwall component modeled in Autodesk Revit. The presence of inclined surfaces and non-uniform cross-sectional dimensions increases the complexity of volume calculations when using conventional methods. Consequently, geometric simplifications applied during manual calculations may contribute to the observed deviation in concrete quantity results.

For reinforcement quantities, the largest differences were identified in the Wing Wall and Abutment components. Although the number and diameter of reinforcing bars were identical in both methods, the BIM model generated varying bar lengths according to the actual geometry of each element. This finding was particularly evident in the Wing Wall component, where several reinforcing bars possessed different actual lengths due to the varying geometry of the structure, despite being represented using similar reinforcement codes in the conventional Bar Bending Schedule (BBS). In contrast, the conventional BBS applied representative lengths for groups of reinforcing bars, simplifying the calculation process. Consequently, quantity deviations emerged because BIM was able to capture geometric variations that were not fully reflected in the conventional approach.

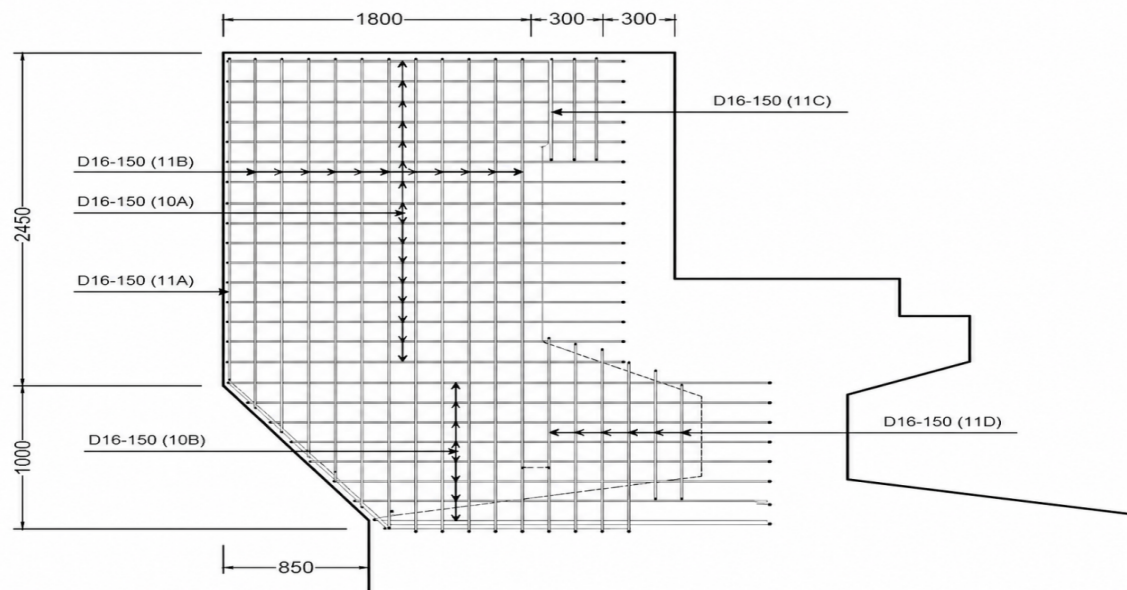


Figure 9. Reinforcement Layout of the Wing Wall Showing Variations in Bar Lengths

Figure 9 illustrates the reinforcement arrangement of the Wing Wall component generated in Autodesk Revit. As shown in the figure, several reinforcing bars have different lengths due to the varying geometry of the structure, particularly in the inclined section of the Wing Wall. During BIM modeling, reinforcement dimensions were adjusted to follow the actual geometry presented in the reinforcement detail drawings. In contrast, the conventional Bar Bending Schedule (BBS) represents groups of reinforcing bars using uniform or representative lengths, which may not fully reflect the geometric variations shown in the drawings. Consequently, differences in reinforcement quantities were observed between the BIM-based and conventional calculations. Conversely, components such as the Base Slab, Deck and Sidewalk, and Bored Pile exhibited very small differences between the two methods. These components possess relatively simple and uniform geometries, allowing conventional calculations to represent actual conditions with a high degree of accuracy. This finding indicates that quantity

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deviations are not solely influenced by the calculation method itself but are also strongly affected by the complexity of structural geometry and reinforcement detailing.

Data Testing and Accuracy Analysis

Further analysis was conducted to evaluate the level of deviation and accuracy between the two methods using the percentage of error formula and the statistical method Root Mean Square Error (RMSE). The results of the error calculation for each structural component and the recapitulation of average accuracy values are presented in Table 2 and Table 3 respectively.

Table 2. Error Test Results

Structural Component	Net			
	Concrete Volume Difference (m ³)	Reinforcement Volume Difference (m ³)	Concrete Error (%)	Reinforcement Error (%)
Abutment	0,015	0,015	0,010	0,721
Wing wall	0,015	0,015	0,138	6,955
Base Slab	0,003	0,003	0,012	0,475
Deck and Sidewalk	0,003	0,003	0,002	0,096
Backwall	0,029	0,000	0,776	1,079
Bored Pile	0,004	0,001	0,003	0,025
Total	0,069	0,037	0,941	9,352

Source: Result of research calculations, 2026

The error analysis presented in Table 2 reveals that deviation levels differ significantly among bridge components. For concrete quantities, the highest error was recorded in the Backwall component (0.776%), while reinforcement quantities showed the highest error in the Wing Wall component (6.955%). These results indicate that deviation is closely related to the physical characteristics of each structural element.

The relatively high concrete error in the Backwall is attributed to its non-prismatic geometry, where inclined surfaces and tapered sections make manual volume calculations more dependent on geometric simplifications. Meanwhile, the high reinforcement error observed in the Wing Wall is primarily associated with variations in reinforcing bar lengths resulting from changes in structural dimensions along the component. Such variations are captured automatically by BIM but are often simplified in conventional reinforcement schedules.

In contrast, structural elements with more regular geometries, such as the Base Slab, Deck and Sidewalk, and Bored Pile, exhibited substantially lower error values. This suggests that conventional quantity calculations remain reliable for simple structural forms but become increasingly susceptible to deviation as geometric complexity and reinforcement variability increase.

To further evaluate the overall accuracy and consistency of the BIM-based quantity take-off results relative to the conventional method, a statistical assessment was performed using the average error percentage and Root Mean Square Error (RMSE). The recapitulation of these values is presented in Table 3.

Table 3. Recapitulation of Accuracy

Parameter	QTO	
	Concrete	Reinforcement
Average Error (%)	0,157	1,559
RMSE (m3)	0,015	0,009

Source: Result of research calculations, 2026

Based on the results presented in Table 3, the average error values obtained were 0.157% for concrete and 1.559% for reinforcement. Meanwhile, the RMSE values were 0.015 m³ for concrete and 0.009 m³ for reinforcement. These RMSE values indicate that the average magnitude of quantity differences between the conventional and BIM-based methods remained very small across all evaluated bridge components. These relatively low error and RMSE values indicate a high level of agreement between the conventional method and the BIM-based quantity take-off results. The findings suggest that BIM can reliably generate quantity information for bridge structures while maintaining consistency with conventional design calculations.

The observed deviation patterns further indicate that quantity differences are not uniformly distributed across all structural components. Components with more complex geometries, such as the Backwall, or with varying reinforcement configurations, such as the Wing Wall and Abutment, tend to exhibit higher deviations than components with regular and repetitive geometries. This demonstrates that the magnitude of quantity deviation is influenced not only by the calculation method but also by the geometric and detailing characteristics of the structural element being evaluated.

These findings are consistent with previous studies by Setiawan et al., (2022) and Adha, 2023, which reported relatively small differences between conventional and BIM-based quantity estimations. However, this study further shows that analyzing deviation at the component level provides additional insight into the factors influencing quantity estimation results. Therefore, BIM not only serves as an accurate quantity take-off tool but also enables a more detailed representation of structural geometry and reinforcement detailing, which is particularly beneficial for bridge components with complex configurations. Furthermore, this component-based deviation analysis represents an additional contribution beyond conventional volume comparison studies, as it provides insight into the underlying factors influencing quantity estimation discrepancies.

CONCLUSION

This study evaluated the quantity take-off (QTO) results of concrete and reinforcement works obtained using conventional calculations and Building Information Modeling (BIM) through Autodesk Revit on the Tanjung Alai Village Bridge project. The comparison results indicate that both methods produce highly similar quantity values, with average error values of 0.157% for concrete and 1.559% for reinforcement. The corresponding RMSE values were 0.015 m³ for concrete and 0.009 m³ for reinforcement, indicating that the overall deviations between the two methods were relatively small. These results confirm a high level of agreement between conventional calculations and BIM-based quantity estimation.

The analysis revealed that quantity deviations vary among bridge components and are influenced by their geometric characteristics and reinforcement detailing. The highest concrete deviation was observed in the Backwall component due to its non-prismatic geometry and the geometric simplifications applied in conventional calculations. Meanwhile, the highest reinforcement deviation occurred in the Wing Wall component, where variations in actual bar lengths were captured by the BIM model but simplified in the conventional Bar Bending Schedule (BBS). In contrast, components with relatively simple and uniform geometries, such as the Base Slab, Deck and Sidewalk, and Bored Pile, exhibited considerably lower deviations.

These findings demonstrate that BIM provides not only accurate quantity estimation results but also a more detailed representation of structural geometry and reinforcement configurations. Furthermore, this study shows that component-level deviation analysis can provide valuable insight into the factors influencing quantity discrepancies between conventional and BIM-based methods, particularly for bridge structures with complex geometries and reinforcement arrangements. The results also highlight that the reliability of quantity estimation is closely related to the ability of the calculation method to represent actual structural conditions, emphasizing the importance of detailed digital modeling for infrastructure projects with complex geometric and reinforcement characteristics.

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