

ANALYSIS OF CONCRETE AND REINFORCEMENT QUANTITY TAKE-OFF OF BRIDGE APPROACH STRUCTURES USING AUTODESK REVIT 2024 AND CONVENTIONAL METHODS

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Abstract

The development of Building Information Modeling (BIM) has accelerated the digitalization of construction planning and management processes, including Quantity Take Off (QTO) calculations that require high speed and accuracy. However, the estimation of concrete and reinforcement quantities for bridge approach structures is still commonly performed using conventional methods, which are prone to calculation errors and require relatively more time. In addition, studies investigating the application of BIM to bridge approach structures with curved geometries remain limited. This study aims to analyze and compare the Quantity Take Off results of concrete and reinforcement obtained using Autodesk Revit 2024 and conventional methods for the bridge approach structures of Sei Kuala and Sei Akar Bridges on the Bagan Jaya–Tembilahan road section. A comparative quantitative research method was employed by developing a three-dimensional model based on project design data and extracting quantity information using the Schedule/Quantity feature in Autodesk Revit 2024. The accuracy of the calculated quantities was evaluated using the Average Error and Root Mean Square Error (RMSE) parameters. The results indicate that Autodesk Revit 2024 is capable of producing quantity estimates that closely correspond to those obtained through conventional methods, with an Average Error of 2.619% for concrete and 5.920% for reinforcement, and RMSE values of 0.473 m³ and 0.656 m³, respectively. The largest deviation was observed in the deck slab reinforcement due to the curved geometry of the bridge approach, which caused Autodesk Revit to calculate the length of each reinforcing bar individually. Overall, the findings demonstrate that Autodesk Revit 2024 can serve as an effective and reliable alternative for performing Quantity Take Off on bridge approach structures with complex geometries.

Keywords: Building Information Modeling (BIM), Autodesk Revit, Quantity Take Off (QTO), Bridge Approach Structure, Reinforcement.

INTRODUCTION

The advancement of digital technology has driven transformation in the construction industry by improving project efficiency, productivity, and execution accuracy. One of the key factors contributing to the success of a construction project is the accuracy of material quantity estimation, commonly known as Quantity Take Off (QTO). The results of QTO calculations serve as the basis for cost estimation, material procurement, and construction management. Therefore, the accuracy of material quantity calculations is a critical factor, particularly in infrastructure projects such as bridges, which consist of numerous structural elements with complex dimensions and detailing (Ihsan & Wacano, 2024; Nafiyah & Martina, 2022).

In practice, Quantity Take Off calculations in construction projects are still widely performed using conventional methods based on two-dimensional drawings, with the assistance of software such as AutoCAD and Microsoft Excel (Sadad et al., 2022; Amri et al., 2023). This method requires a high level of precision because the entire process of identifying dimensions and calculating quantities is performed manually. In addition to requiring a relatively longer processing time, conventional methods are also prone to errors caused by human factors, such as misinterpretation of drawings, dimensional inconsistencies, and inaccuracies in material quantity calculations (Tigauw et al., 2023; Piter & Sucita, 2024; Setiawan et al., 2022). These risks become even greater in bridge structures with complex geometries and multiple interconnected components, such as abutments, wing walls, pile caps, deck slabs, parapets, and piles. Along with technological advancements in the Architecture, Engineering, and Construction (AEC) sector, Building Information Modeling (BIM) has increasingly been adopted as a solution to improve the quality of planning and management in construction projects (Farizah, 2024; Wahyudi & Triana, 2025). BIM enables

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the integration of geometric information, material specifications, work quantities, and construction data into a single coordinated digital model (Wiranti et al., 2022). One of the most widely used BIM-based software applications is Autodesk Revit, which is capable of generating three-dimensional models while simultaneously performing automated material quantity calculations through its Schedule/Quantity feature (Asih et al., 2022). This capability enables the Quantity Take Off process to be carried out more quickly, consistently, and in an integrated manner compared to conventional methods (Sari et al., 2024).

Several previous studies have shown that the implementation of BIM using Autodesk Revit can improve the efficiency and accuracy of material quantity calculations. According to Farizah et al. (Farizah, 2024) demonstrated that Autodesk Revit can produce more effective Quantity Take Off calculations for bridge structural works. Sadad et al. (Sadad et al., 2022). reported that the implementation of BIM in bridge abutment structures produced material quantity estimates that closely matched the planned volumes. Adha's study (Adha et al., 2023) found a reinforcement quantity deviation of 4.04% between the BIM-based method and the conventional method. Meanwhile, Piter and Sucita (Piter & Sucita, 2024) reported a volume deviation of 5.95% in underpass bridge structural works due to differences in calculation methods and the potential for manual errors. In addition, several other studies have also demonstrated that BIM can enhance the effectiveness and efficiency of quantity estimation for various types of reinforced concrete structures (Fadlilah et al., 2024; Maghfirona et al., 2023).

Although numerous studies have been conducted on the application of BIM for Quantity Take Off, most have focused on building structures, specific structural elements, or partial sections of bridges. Furthermore, the research objects generally possess relatively simple geometries, which do not fully represent the complexity of modeling infrastructure structures. Studies specifically comparing concrete and reinforcement Quantity Take Off for an entire bridge approach structure with curved geometry using Autodesk Revit 2024 remain relatively limited. The curved geometry of a bridge approach structure increases modeling complexity because it affects the formation of concrete elements, reinforcement configurations, and the process of extracting material quantities from the three-dimensional model. This condition has the potential to produce different levels of calculation accuracy compared to structures with linear geometries, which have been commonly examined in previous studies. Furthermore, evaluations of calculation accuracy using the Average Error and Root Mean Square Error (RMSE) parameters for bridge approach structures with such characteristics have rarely been reported in previous research.

Based on these conditions, this study aims to analyze and compare the Quantity Take Off results of concrete and reinforcement obtained using Autodesk Revit 2024 and conventional methods for a bridge approach structure with curved geometry. The findings are expected to provide insights into the accuracy of BIM implementation in structures with higher modeling complexity and to serve as a reference for the further development of BIM applications in bridge construction projects.

METHOD

Research Methodology

This study employed a comparative quantitative method to compare the results of concrete and reinforcement Quantity Take Off (QTO) obtained using Autodesk Revit 2024 with those generated through conventional methods. The comparison was conducted on the concrete volumes and reinforcement weights of the bridge approach structure of the Sei Kuala and Sei Akar Bridges on the Bagan Jaya–Tembilahan road section. The calculation results from both methods were then analyzed to determine the level of agreement and the accuracy of the quantities obtained.

Data Collection

The data were collected during a five-month internship conducted on the project, providing the researcher with direct access to the technical documents used in the planning and construction processes. In addition, field observations were carried out to understand the characteristics of the bridge approach structure, particularly in sections with curved geometry, thereby enabling the Autodesk Revit 2024 model to represent the design conditions more accurately.

Structural Modeling Using Autodesk Revit 2024

The modeling process was carried out by developing a three-dimensional model of the bridge approach structure based on the project's construction drawings and technical specifications. The modeled structural elements included piles, pile caps, abutments, wing walls, approach slabs, parapets, and other structural components comprising the bridge approach structure. The bridge approach structure investigated in this study has a curved geometry, requiring a different modeling approach from that used for linear structures. The concrete elements were modeled using the Sweep feature to create concrete geometries that follow the bridge approach alignment in

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accordance with the actual design configuration. This method was selected because it provides a more accurate representation of geometries in structures with curved shapes.

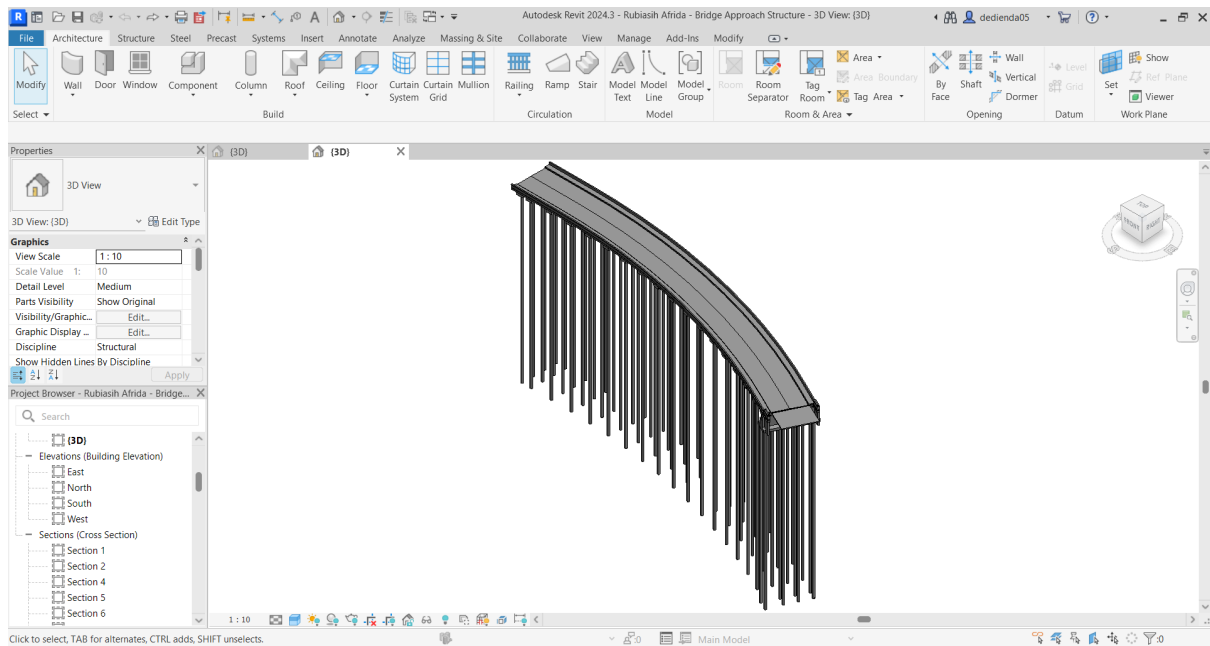


Figure 1. Bridge Approach Structure Modeling

After the concrete modeling was completed, the reinforcement modeling process was carried out using the Path Reinforcement and Surface Reinforcement features. Path Reinforcement was used to model reinforcing bars that follow the alignment of structural elements, while Surface Reinforcement was used to distribute reinforcement across the surfaces of concrete elements. The use of these two features enabled the reinforcement configuration to conform to the curved geometry of the structure, resulting in a model representation that more closely reflected the design conditions.

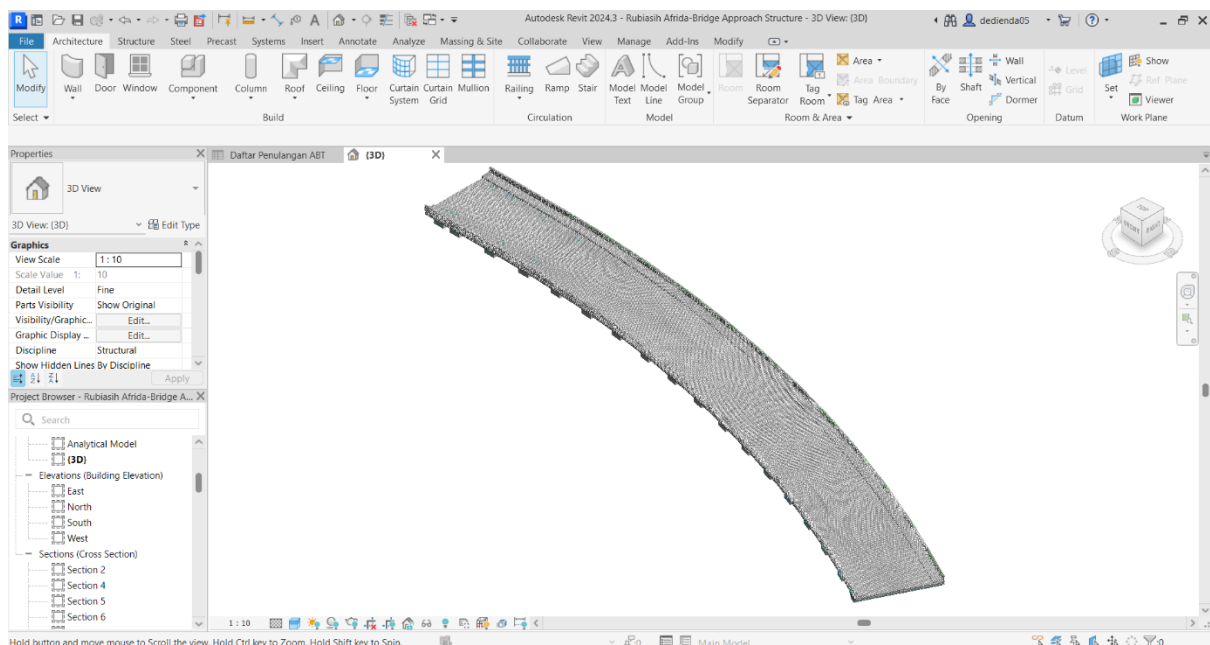


Figure 2. Curved Reinforcement Modeling

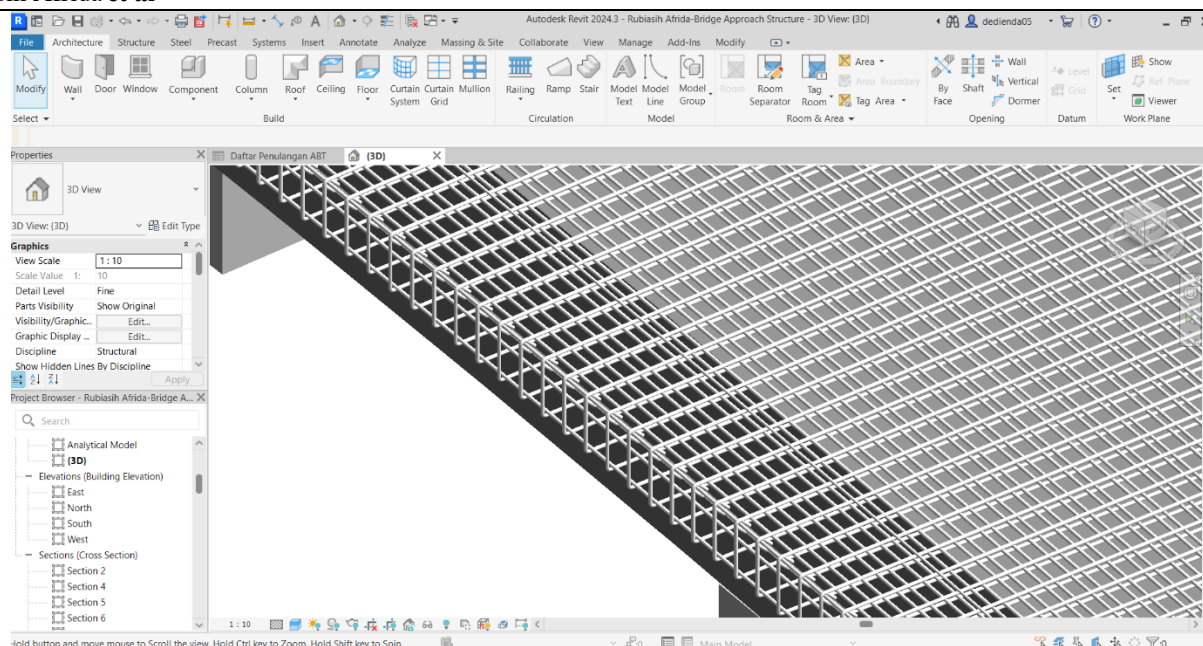


Figure 3. Reinforcement Detail

Concrete and Reinforcement Quantity Take Off

A. Analysis of the Conventional Method

At this stage, the Quantity Take Off (QTO) calculation was performed using the conventional method based on two-dimensional design drawings. The quantity calculations were carried out manually by referring to the Detail Engineering Design (DED) drawings, where the dimensions of each structural element were obtained from the design drawings and subsequently calculated using the following equations:

1. Gross Concrete Volume Calculation

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

Where:

- V_{ki} = Gross concrete volume of bridge component *i* (m³)
- N = Number of units of bridge component *i*
- A = Cross-sectional area of bridge component *i* (m²)
- L = Length of bridge component *i* (m)

2. Reinforcement Volume Calculation

$$V(T.i) = W(T.i) \rho_{steel} \quad (2)$$

Where:

- V(T,i) = Volume of reinforcement in bridge component *i* (m³)
- W(T,i) = Weight of reinforcement in bridge component *i* (kg)
- ρ_{steel} = Density of reinforcing steel (7,850 kg/m³)

3. Net Concrete Volume Calculation

$$V(B.i) = V(K.i) - V(T.i) \quad (3)$$

Where:

- V(B,i) = Net concrete volume of bridge component *i* (m³)
- V(K,i) = Gross concrete volume of bridge component *i* (m³)
- V(T,i) = Reinforcement volume of bridge component *i* (m³)

B. Analysis of BIM-Based Quantity Take Off (QTO)

After the three-dimensional model had been completed, the Quantity Take Off process was carried out using the Schedule/Quantity feature in Autodesk Revit 2024. This feature was used to automatically extract quantity data based on the information embedded in each model element. The generated data included concrete volumes (m³) and

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reinforcement weights (kg) for each structural component. The Quantity Take Off results obtained from Autodesk Revit were then compared with those calculated using the conventional method to determine the level of discrepancy for each structural element.

C. Comparative Analysis of BIM-Based and Conventional Methods

To evaluate the differences in calculation results between the conventional method and the BIM-based method, percentage error and Root Mean Square Error (RMSE) analyses were employed as indicators of the accuracy and deviation of the calculated quantities. The following equations were used to determine the percentage error and RMSE values.

$$Error (\%) = \frac{V.konvensional - V.rev\text{it}}{V.konvensional} \times 100 \% \quad (4)$$

Where:

Vconventional = Quantity obtained from the conventional method

Vrevit = Quantity obtained from the Autodesk Revit method

$$RSME = \sqrt{\frac{\sum (y_i - y')^2}{n}} \quad (5)$$

Where:

Y' = QTO value obtained from the conventional method

Y = QTO value obtained from the BIM-based method

N = Total number of samples used in the analysis

RESULTS AND DISCUSSION

Gross Concrete Quantity Take-Off Results

The results of the gross concrete Quantity Take Off (QTO) obtained using Autodesk Revit 2024 and the conventional method are presented in Table 1.

Table 1. Gross Concrete Volume

Component Element	Gross Concrete Volume		
	Conventional Method (m ³)	Revit Method (m ³)	Difference (m ³)
Abutment	41,412	41,454	-0,042
Wing wall	4,404	4,265	0,139
Approach Slab	7,079	7,079	0,000
Pile Cap	120,662	120,662	0,000
Sidewalk	42,225	42,559	-0,334
Parapet Wall	27,235	27,284	-0,049
Deck Slab	310,464	312,691	-2,227
Backwall	1,416	1,681	-0,265
Driven Pile	593,761	595,084	-1,323

The comparison of gross concrete volumes indicates that most structural elements exhibit a high level of agreement between the conventional method and Autodesk Revit 2024. The largest volume differences were observed in the deck slab, with a deviation of 2,227 m³, and the driven pile, with a deviation of 1,323 m³. Meanwhile, the approach slab and pile cap showed no volume differences between the two methods.

Reinforcement Quantity Take-Off Results

Table 2. Reinforcement Volume

Component Element	Reinforcement Volume		
	Conventional Method (m ³)	Revit Method (m ³)	Difference (m ³)
Abutment	0,602	0,580	0,022
Wing wall	0,075	0,077	-0,002
Approach Slab	0,186	0,187	-0,001
Pile Cap	1,854	1,857	-0,003
Sidewalk	0,000	0,000	0,000
Parapet Wall	0,409	0,404	0,005
Deck Slab	4,701	6,667	-1,966
Backwall	0,010	0,010	0,000
Driven Pile	10,315	10,319	-0,004

The Quantity Take-Off results for the reinforcement show that most structural elements have only a relatively small volume difference. The volume differences for the abutment, wing wall, approach slab, pile cap, parapet, backwall, and driven pile range from 0,001 m³ to 0,022 m³, indicating a high degree of agreement between the two methods.

However, a fairly significant discrepancy was found in the deck slab element: the reinforcement volume is 4,701 m³ according to the conventional method and 6,667 m³ according to Autodesk Revit 2024. The difference amounts to 1,966 m³, which is the largest deviation compared with the other structural elements.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Bar Diameter	Family and Type	A	B	C	D	E	H1	H2	Bar Length	Quantity	Total Bar Length	Berat (Kg/m)	Berat total (Kg)
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82238 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.238 m	1	82.238 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82295 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.295 m	1	82.295 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82353 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.353 m	1	82.353 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82410 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.410 m	1	82.410 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82467 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.467 m	1	82.467 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82525 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.525 m	1	82.525 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82582 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.582 m	1	82.582 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82640 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.640 m	1	82.640 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82697 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.697 m	1	82.697 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82754 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.754 m	1	82.754 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82812 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.812 m	1	82.812 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82869 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.869 m	1	82.869 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82927 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.927 m	1	82.927 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	82984 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	82.984 m	1	82.984 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83041 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.041 m	1	83.041 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83099 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.099 m	1	83.099 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83156 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.156 m	1	83.156 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83214 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.214 m	1	83.214 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83271 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.271 m	1	83.271 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83328 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.328 m	1	83.328 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83386 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.386 m	1	83.386 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83443 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.443 m	1	83.443 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83501 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.501 m	1	83.501 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83558 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.558 m	1	83.558 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83615 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.615 m	1	83.615 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83673 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.673 m	1	83.673 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83730 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.730 m	1	83.730 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83787 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.787 m	1	83.787 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83845 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.845 m	1	83.845 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83902 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.902 m	1	83.902 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	83960 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	83.960 m	1	83.960 m		0.000 kg
16 mm	Rebar Bar: D16-125 mm (tulangan plat lantai 3)	84017 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	84.017 m	1	84.017 m		0.000 kg

Figure 4. Reinforcement schedule using Revit

The difference in reinforcement volume is primarily caused by the curved geometry of the approach slope. The Autodesk Revit 2024 schedule shows that each reinforcement bar has a different length according to the actual shape of the structure, whereas the conventional method assumes a uniform bar length. As a result, Autodesk Revit provides a more detailed reinforcement-volume estimate that better reflects the true geometric condition.

Net Concrete Quantity Take-Off Result

Table 3. Net concrete volume

Component Element	Net Concrete Volume		
	Conventional Method (m ³)	Revit Method (m ³)	Difference (m ³)
Abutment	40,810	40,874	-0,064
Wing wall	4,329	4,188	0,141
Approach Slab	6,893	6,892	0,001
Pile Cap	118,808	118,805	0,003
Sidewalk	42,225	42,559	-0,334
Parapet Wall	26,826	26,880	-0,054
Deck Slab	305,763	306,024	-0,261
Backwall	1,406	1,671	-0,265
Driven Pile	583,446	584,765	-1,319

Based on Table 3, the clean-concrete calculations obtained with Autodesk Revit 2024 show a high degree of agreement with the conventional method. Most elements exhibit only minor volume differences; the largest deviation occurs in the driven-pile element at 1,319 m³, while the smallest deviations are observed in the approach slab and pile cap, at 0,001 m³ and 0,003 m³ respectively.

Accuracy evaluation

Table 4. Accuracy test

Parameter	QTO	
	Concrete	Reinforcement
Average Error (%)	2,619	5,920
RSME (m3)	0,473	0,656

Based on the evaluation results, Autodesk Revit 2024 demonstrates a good level of accuracy when performing Quantity Take-Off for the bridge approach structure. The average error obtained for concrete and reinforcement is 2,619 % and 5,920 %, respectively, with RMSE values of 0,473 m³ for concrete and 0,656 m³ for reinforcement. Although there is a relatively high deviation for the deck-slab element, overall the differences in the calculations remain within acceptable limits. These findings indicate that Autodesk Revit 2024 can generate concrete- and reinforcement-quantity estimates that closely match the conventional method, while also providing a more detailed representation of elements with curved geometry. To provide a clearer illustration, the comparison results of concrete and reinforcement quantities obtained using the conventional method and the BIM-based method with Autodesk Revit for each bridge structural component are presented in Figures 5 and 6.

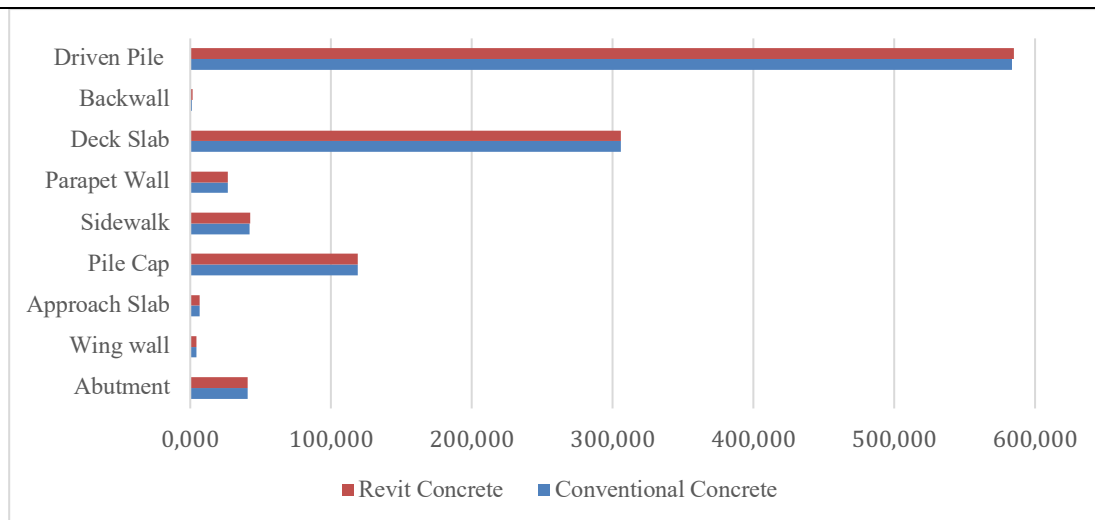


Figure 5. Comparison of Conventional and BIM (Revit) Concrete Methods

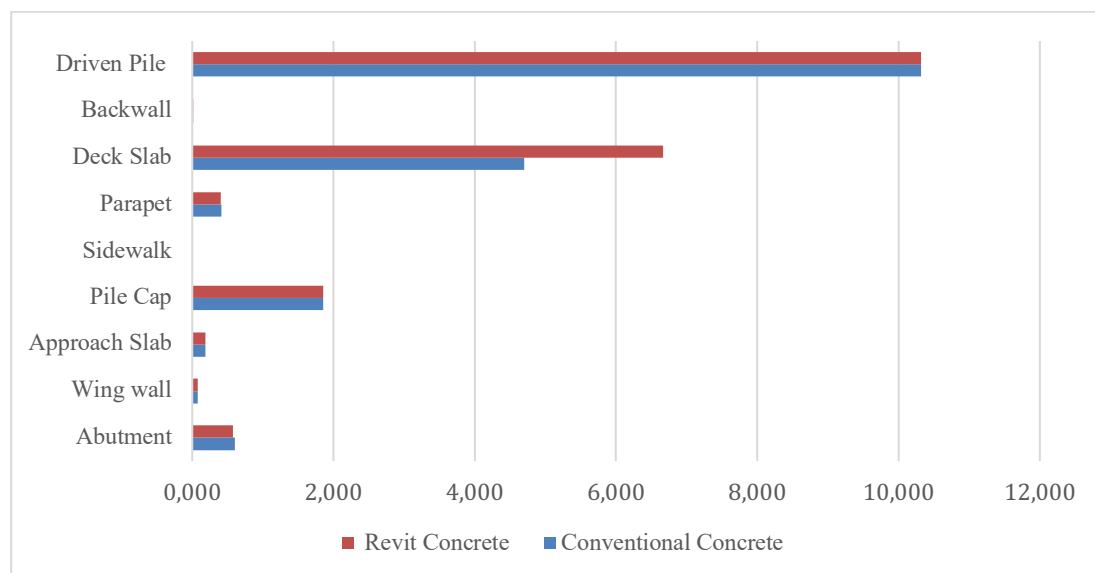


Figure 6. Comparison of Conventional and BIM (Revit) Reinforcement Methods

CONCLUSION

This study aimed to analyze and compare the results of concrete and reinforcement Quantity Take Off (QTO) for a bridge approach structure using Autodesk Revit 2024 and conventional methods. The findings indicate that Autodesk Revit 2024 is capable of producing quantity estimates that closely correspond to those obtained through conventional methods, with an Average Error of 2.619% for concrete and 5.920% for reinforcement, and RMSE values of 0.473 m³ and 0.656 m³, respectively. The differences in concrete quantity calculations were relatively small for most structural elements, whereas the largest deviation was observed in the deck slab reinforcement due to the curved geometry of the bridge approach. Autodesk Revit 2024 was able to calculate the actual length of each reinforcing bar individually according to the structural geometry, resulting in more detailed quantity estimates than the conventional method, which assumes uniform reinforcement lengths. Therefore, the implementation of BIM using Autodesk Revit 2024 can serve as an effective and reliable alternative for the Quantity Take Off process of bridge approach structures. The findings also indicate that the influence of curved geometry on reinforcement Quantity Take Off results is more significant than its effect on concrete volume calculations.

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