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IMPLEMENTATION OF BUILDING INFORMATION MODELING (BIM) FOR BRIDGE ABUTMENT COST ESTIMATION CONSIDERING QTO VALIDITY

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ABSTRACT

This study investigates the application of Building Information Modeling (BIM) for cost estimation of bridge abutment structures, focusing on the validity of Quantity Take-Off (QTO). Poor QTO accuracy is a critical issue in construction projects, often leading to discrepancies in material estimates and cost overruns. This research aims to compare the conventional QTO methods with BIM-based QTO for the X bridge abutment structure, focusing on the accuracy of material quantities such as concrete and steel reinforcement. The methodology uses Autodesk Revit for 3D BIM modeling, clash detection with Autodesk Navisworks Manage, and QTO accuracy evaluation through the Mean Absolute Percentage Error (MAPE). The findings show that BIM-based QTO produces more accurate results, with deviations of 7.73% for sand and concrete, and 9.39% for reinforcement steel compared to conventional methods. These results highlight BIM's potential to improve cost estimation accuracy in infrastructure projects, reducing the risk of underpayments or overpayments. The research implications suggest that BIM adoption could enhance efficiency and accuracy in Indonesian construction projects, offering significant benefits for cost management and project execution. This study contributes to understanding BIM's role in bridge construction cost estimation and emphasizes its practical advantages over traditional methods.

KEYWORDS *QTO, BIM, RAB, Bridge Abutment, MAPE*

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INTRODUCTION

The enhancement of efficiency and effectiveness in construction projects through digital technology has become a priority in modern infrastructure planning. The Directorate General of Bina Marga, Republic of Indonesia, continues to promote the implementation of Building Information Modeling (BIM) in road and bridge construction processes to improve, accelerate, and optimize existing workflows, commonly referred to as Better, Faster, Cheaper, ensuring that

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technology adoption adds value (J. Zhang et al., 2023) (Directorate General of Highways of the Ministry of Public Works and Housing, 2023) . BIM has emerged as a significant construction technology within the Architecture, Engineering & Construction (AEC) industry, facilitating processes from planning and design to construction and facility operation (Azhar, 2011) .

Quantity Take-off (QTO) is a method for calculating material volumes in construction projects, enabling cost management, investment analysis, decision-making, and resource planning (Doloi, 2011). The primary advantage of BIM-based QTO is its ability to provide a faster and more comprehensive process in the early project phases, allowing for detailed cost analysis with reliable outcomes. (Gołaszewska & Salamak, 2017) However, it is crucial to explore the validation of QTO results by comparing conventional and BIM methodologies to identify the limitations of BIM applications in QTO activities (Antunes, 2018).

Research on the comparison of BIM-based and conventional QTO for bridge structures has been conducted using the Nemetschek Allplan BIM software, focusing on bridge structures. This study assessed how BIM enhances material estimation accuracy compared to conventional methods while identifying factors influencing discrepancies in QTO results. The findings revealed a 7.09% deviation in concrete calculations using BIM compared to conventional methods, while reinforcement calculations showed a 14.87% lower deviation in BIM-based QTO. These discrepancies stemmed from limitations in Allplan's features, particularly in defining reinforcement hook lengths, which did not conform to the Indonesian National Standards (SNI). However, the study did not evaluate deviations in cost estimation. Saputra et al (2024)

Nafiyah & Martina (2022) conducted a study on QTO using BIM and conventional methods with Autodesk Revit, yielding deviations of ±0.32% for concrete volume and ±2.28% for reinforcement volume, with BIM-based QTO producing lower values. The accuracy and level of detail in BIM modeling, influenced by user experience, significantly impacted QTO results and project costs. A similar study by focusing on QTO for bridge abutment structures using Autodesk Revit 2022, showing deviations of 1.31% for bored piles, 3.335% for pile caps, 1.527% for breast walls, 5.901% for wing walls, and 0.859% for counterfort walls, with all BIM-based QTO results being lower than conventional estimates. Sadad et al (2022)

Similar studies on building projects have also been extensively discussed. For example, comparing QTO results between BIM and conventional methods consistently demonstrates lower deviations in BIM-based QTO than conventional calculations. These findings suggest similar trends may apply to infrastructure projects, including bridges. Simatupang et al (2024) Whang & Min (2016)

Among the various BIM software available, Autodesk Revit is the most widely used, with a 46% adoption rate, according to The National BIM Report, The NBS (2019). Autodesk Revit is utilized for project management, control, drafting, and quantity estimation (Zuo et al., 2020) By leveraging Revit, contractors benefit from improved scheduling and resource utilization efficiency, which minimizes design life cycles, enhances quality, and ensures accurate construction documentation. However, despite BIM's advantages in efficiency and accuracy, its effective implementation requires expertise in 3D modeling to ensure accurate quantity estimations. (Nan et al., 2016) (Herdyana & Suroso, 2023)

The advancement of technology in the construction industry has driven the adoption of BIM as an alternative to conventional methods for quantity and cost estimation. BIM enhances efficiency and accuracy in cost estimation compared to conventional approaches that rely on contractor field measurements and Microsoft Excel. However, adoption of BIM requires technical expertise and software investment. Additionally, the use of clash detection is essential to validate designs before the construction phases (Sacks et al., 2018) (Nur Dhou & Susanto, 2023) (Sacks et al., 2018; Yönder & Çavka, 2024) .

The bridge span was extended from 25 m to 35.8 m in the Bridge X Replacement Project. This study aims to analyze and compare the QTO and cost estimation accuracy for Abutment between BIM-based calculations and contractor estimates, identifying causes of QTO deviations. Research on BIM applications in bridge substructure projects remains limited compared to studies on building projects.

The study focuses on comparing the accuracy of quantity take-off calculations between BIM using Autodesk Revit and conventional methods for bridge abutments, which involve varied concrete material compositions across different sections, including mass concrete fc' 35 MPa for footings and abutment heads, as well as structural concrete fc' 35 MPa for abutment walls, stoppers, ornament bases, back walls, wing walls, and abutment approach slabs. Due to the complexity of 3D modeling for these elements, this research is expected to significantly contribute to the academic field of QTO, addressing substantial financial risks in bridge and infrastructure projects arising from overpayments or underpayments. Additionally, the study serves as a risk mitigation strategy for project deviations, particularly in government-managed infrastructure projects.

While previous studies have examined the application of Building Information Modeling (BIM) in construction projects, especially in quantity take-offs (QTO), there remains a gap in exploring the specific benefits and challenges of applying BIM for cost estimation in bridge construction. Many studies have focused on comparing BIM and conventional methods for various construction projects, but fewer have assessed the accuracy and efficiency of BIM in estimating costs for infrastructure projects like bridges, particularly concerning the accuracy of QTO for abutment structures. Furthermore, the limited application of BIM in Indonesia's construction industry, especially in bridge substructures, highlights the need for more localized research focusing on practical implementations and the potential financial implications of adopting BIM technology in cost estimation processes.

This research introduces a novel approach by focusing on using Building Information Modeling (BIM) for cost estimation in bridge projects, particularly estimating costs for abutment structures. While BIM has been applied to building projects, its integration into bridge substructure estimation is still underexplored. The study not only evaluates the accuracy of Quantity Take-Off (QTO) through BIM but also compares it with conventional methods, offering insights into how BIM can reduce discrepancies in cost estimation, improve accuracy, and mitigate the risk of cost overruns. The use of BIM for clash detection, the creation of detailed 3D models, and its effect on cost estimation precision in the context of bridge construction represents a significant contribution to the field.

The primary objective of this research is to evaluate the effectiveness of Building Information Modeling (BIM) in estimating the cost of abutment structures for bridges, focusing specifically on the accuracy of Quantity Take-Off (QTO) calculations. By comparing the results obtained from BIM with conventional methods, this study aims to determine the discrepancy in cost estimation and assess how BIM can improve the overall efficiency and reliability of the cost estimation process. The research also seeks to identify factors that influence the accuracy of QTO and offer recommendations for better integration of BIM in construction project management.

This research offers significant benefits for both academic and practical purposes. Academically, it contributes to the body of knowledge by addressing the application of BIM in cost estimation for bridge construction, an underexplored topic. For practitioners, particularly those involved in bridge construction projects in Indonesia, the findings provide a comprehensive understanding of how BIM can enhance the accuracy of cost estimations, improve efficiency in the early stages of construction, and reduce the risks of cost discrepancies. By offering practical insights into the implementation of BIM, this study also supports adopting more accurate and effective cost estimation methods in infrastructure projects, ultimately leading to better project outcomes and reduced financial risks.

RESEARCH METHOD

The method used in this study is a quantitative research method that implements Building Information Modeling (BIM) to evaluate the accuracy of Quantity Take-Off (QTO) for the abutment structure of a bridge. The research compares the QTO calculations obtained from BIM modeling with those derived from conventional methods. By utilizing Autodesk Revit 2024 for 3D modeling and integrating various plug-ins, such as SOFiSTiK for reinforcement design, the study aims to assess the efficacy of BIM in producing more accurate material estimations for construction projects. The quantitative approach is designed to measure discrepancies between BIM-based and traditional QTO results and evaluate the efficiency of BIM in terms of time, accuracy, and resource management.

Data collection was conducted using secondary data, including shop drawings, Detail Engineering Design (DED), and the QTO calculation results from contractors. These data were used to compare with the BIM-generated QTO values. The BIM methodology begins with creating a detailed 3D model of the abutment structure, including all necessary elements such as the foundation, concrete, and reinforcement. The study also integrates Autodesk Navisworks for clash detection, ensuring the model is free from design conflicts before initiating the QTO process. The BIM model undergoes several steps, such as family model creation, reinforcement design, clash detection, and QTO export, ultimately allowing for a thorough comparison between the two methods.

This study's data analysis focuses on assessing the accuracy of the BIM-based QTO using Mean Absolute Percentage Error (MAPE). This quantitative metric compares the BIM QTO results with the conventional QTO calculations. The MAPE formula is applied to determine the percentage error between the two methods and assess the precision of BIM in cost estimation. By measuring the variance between the QTO results from BIM and traditional methods, the study aims to provide empirical evidence of BIM's effectiveness in improving the accuracy of material quantity estimates, which is critical in ensuring that construction projects stay within budget and meet the required specifications. The findings are then analyzed to suggest improvements and identify the potential benefits of adopting BIM in infrastructure projects, particularly for bridges.

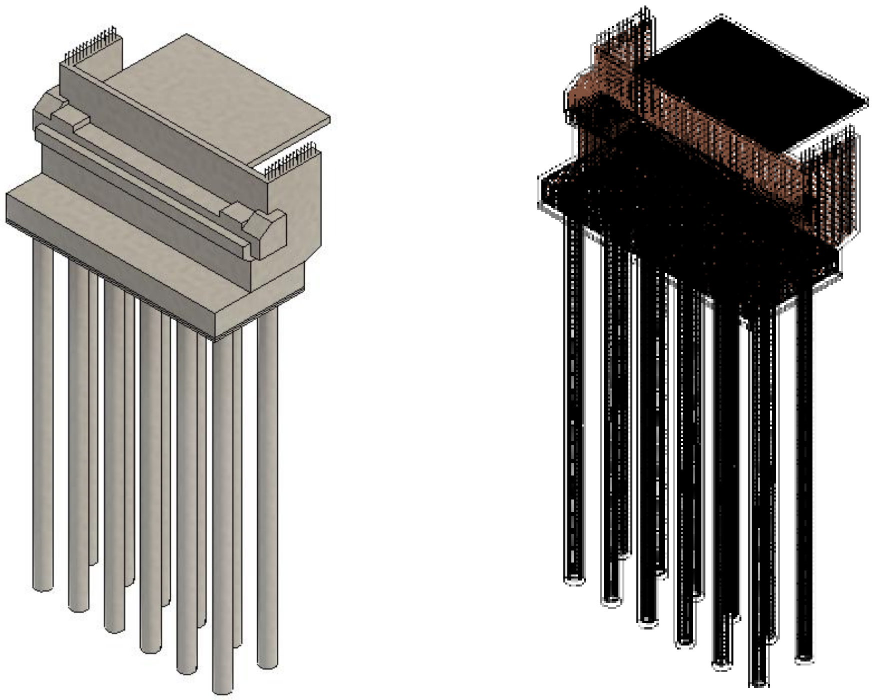
RESULT AND DISCUSSION

Implementation of 3D Building Information Modeling (BIM)

The implementation of BIM 3D for *shop drawing abutments* provides an advantage in detail and coordination (Andiyan, 2020; Disney, et al., 2023; Igba Emmanuel et al., 2024) . BIM 3D is a development from a 2D model that was initially geometric to a visual parametric model. (Inzerillo et al., 2023) These advantages include structural *modeling*, repetition details, coordination with other components, specifications and materials, and good review and validation. Using BIM allows for better visualization and more effective coordination between different disciplines in construction projects (Inzerillo et al., 2023; Muñoz-La Rivera, Vielma, Herrera, & Carvallo, 2019; Alcinia Z. Sampaio & Gomes, 2022; Alcinia Zita Sampaio, Sequeira, Gomes, & Sanchez-Lite, 2023; Singh, Mahmoodian, & Wang, 2025; S. Zhang et al., 2024) (Samimpay & Saghatforoush, 2020) .

The creation of drawings with Building Information Modeling (BIM) starts by making families related to the abutment and abutment parts so that the resulting QTO results are detailed according to the materials in the specifications of the X bridge. *abutment*, i.e., Concrete structure, fc' 35 MPa, and Concrete large volume structure, fc'35 MPa.

After creating a *complete family for the X bridge's abutment structure, the family is merged into the Revit Project so that a rebar schedule can be made for each part of the abutment's* completeness.



(a) **(b)**

Figure 1. Display on Revit (a) 3D *abutment*; (b) Abutment Recurrence

Performing *a 3D clash detection* model check

After 3D modeling and repetition, the next step is to check *clash detection* using Autodesk Revit (feature: *Interference Check*) and Autodesk Navisworks Manage 2024.

Next, it is validated again with Autodesk Navisworks Manage by exporting it to a file with the nwc extension. A tolerance of 0.02 m is used in this model, to accommodate the bending of the reinforcement that is too close due to the relatively large and tight accumulation of reinforcement for the *abutment part* of this bridge, besides that the use of multi-material on one abutment also affects the checking of clash detection because there is a reinforcement between the abutment parts that enter the other parts but is considered a clash. For example, reinforcement on the abutment body is related to the concrete footing; this can be considered a clash. After checking that clash detection does not occur in the model, the calculation of QTO from the 3D BIM model can be continued.

***Exporting* QTO *abutment* with BIM**

After the model validation process is completed, QTO calculations are exported into *Microsoft Excel software for data processing and MAPE calculations. The export step is carried out with the help of the Dynamo plug-in. The file made from Dynamo exports* the QTO into *text* form for the initial stage, which we can then change the format to a Microsoft Excel file. The purpose of *this export* is to process QTO data more quickly.

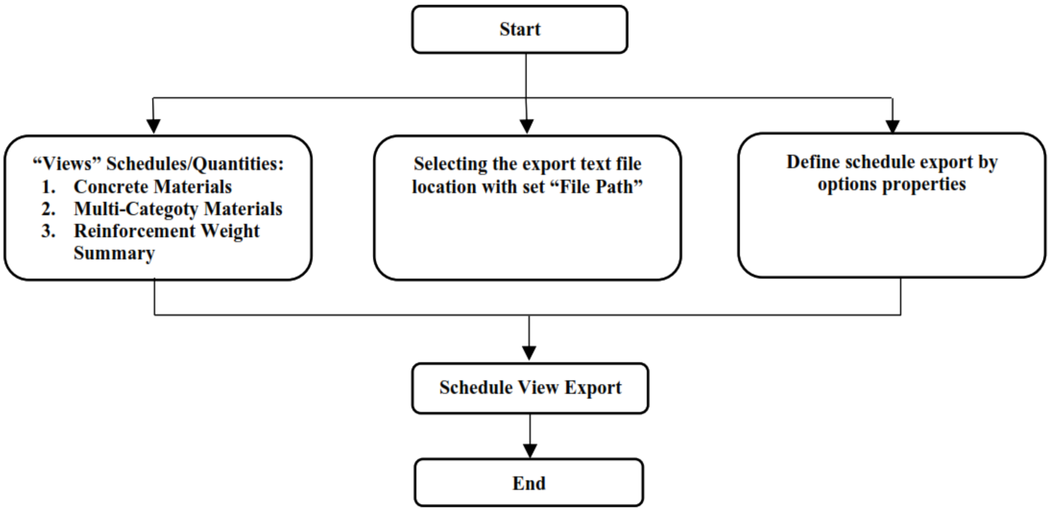
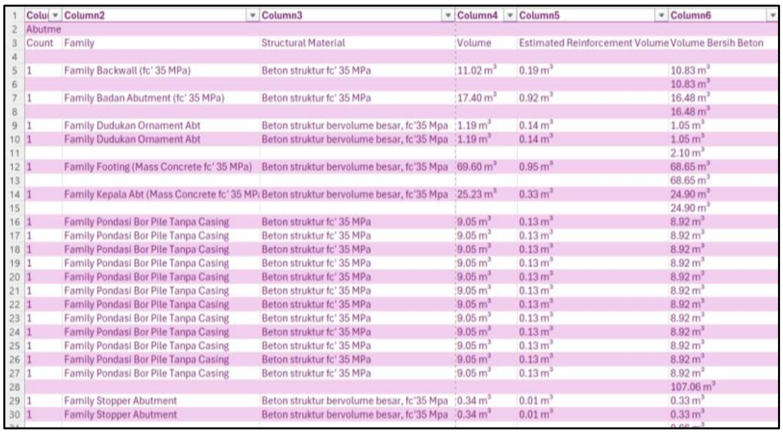


Figure 2. Dynamo Revit Algorithm

The file is *exported* to MS Excel to give a good view, and can be further processed using the Delimiter "TAB." Then, the column display will be separate according to each piece of data, as shown in Figure 3.



1	Colu	Column2	Column3	Column4	Column5	Column6
2	Abutme					
3	Count	Family	Structural Material	Volume	Estimated Reinforcement Volume	Volume Bersih Beton
4						
5	1	Family Backwall (fc' 35 MPa)	Beton struktur fc' 35 MPa	11.02 m³	0.19 m³	10.83 m³
6						10.83 m³
7	1	Family Badan Abutment (fc' 35 MPa)	Beton struktur fc' 35 MPa	17.40 m³	0.92 m³	16.48 m³
8						16.48 m³
9	1	Family Dudukan Ornament Abt	Beton struktur bervolume besar, fc'35 Mpa	1.19 m³	0.14 m³	1.05 m³
10	1	Family Dudukan Ornament Abt	Beton struktur bervolume besar, fc'35 Mpa	1.19 m³	0.14 m³	1.05 m³
11						2.10 m³
12	1	Family Footing (Mass Concrete fc' 35 MPa)	Beton struktur bervolume besar, fc'35 Mpa	69.60 m³	0.95 m³	68.65 m³
13						68.65 m³
14	1	Family Kepala Abt (Mass Concrete fc' 35 MP	Beton struktur bervolume besar, fc'35 Mpa	25.23 m³	0.33 m³	24.90 m³
15						24.90 m³
16	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
17	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
18	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
19	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
20	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
21	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
22	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
23	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
24	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
25	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
26	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
27	1	Family Pondasi Bor Pile Tanpa Casing	Beton struktur fc' 35 MPa	9.05 m³	0.13 m³	8.92 m³
28						107.06 m³
29	1	Family Stopper Abutment	Beton struktur bervolume besar, fc'35 Mpa	0.34 m³	0.01 m³	0.33 m³
30	1	Family Stopper Abutment	Beton struktur bervolume besar, fc'35 Mpa	0.34 m³	0.01 m³	0.33 m³

Figure 3. Concrete QTO *export* view on Microsoft Excel

The QTO results must be further processed according to the data that needs to be known. Therefore, the QTO calculation results are obtained from the X bridge's material per abutment structure work in Table 1.

Table 1. Volume recapitulation of QTO material from BIM

No.	*Family/Type*	Volume (m³)	*Estimated Reinforcement Volume* (M3)	Concrete Net Volume (M3)	Total Concrete Net Volume (m3)	Rebar Weight (kg)	Des.
1	Bore pile *foundation*	9,05	0,13	8,92	107,04	11.908,65	Payment Item Per Meter (Concrete

							drill post, 800mm diameter). Self-Compacted Concrete f 'c 30 MPa and Steel Rebar
2	Sand Sand	5,17	-	5,17	5,17	-	Selected piles from the excavated source
3	Work floor	5,17	-	5,17	5,17	-	Concrete , fc'15 Mpa
4	Abt – *Footing*	69,60	0,95	68,65	68,65	7.357,22	Large volume structural concrete, fc'35 MPa and BjTS 420A Fin Rebar Steel
5	Abt – Body	17,40	0,92	16,48	16,48	7.441,99	Structural concrete, f 'c 35 MPa and BjTS 420A Fin Rebar Steel
6	Abt - Head	25,23	0,33	24,90	24,90	2.407,19	Large volume structural concrete, fc'35 MPa and BjTS 420A Fin Rebar Steel
7	Abbot - *Stopper*	0,34	0,01	0,33	0,66	162,03	Structural concrete, f 'c 35 MPa and BjTS 420A Fin Rebar Steel
8	Abbot – D. Ornaments	1,19	0,14	1,05	2,10	2.169,76	Structural concrete, f 'c 35 MPa and BjTS 420A Fin

							Rebar Steel
9	Abt – *Back wall*	11,02	0,19	10,83	10,83	1.595,13	Structural concrete, f 'c 35 MPa and BjTS 420A Fin Rebar Steel
10	Abt – *Wing wall*	6,30	0,11	6,19	12,38	1.871,05	Structural concrete, f 'c 35 MPa and BjTS 420A Fin Rebar Steel
11	Abt – Stepping Plate	12,00	0,34	11,66	11,66	2.642,88	Structural concrete, f 'c 35 MPa and BjTS 420A Fin Rebar Steel
	Sum				**265,04**	**37.440,03**	

QTO Calculation Accuracy Comparison

The conventional QTO calculation for *the abutment of the X bridge has been carefully detailed in the backup of validated contractor data and has undergone thorough supervision and approval from the supervisory consultant and the work owner. This data backup* includes a QTO calculation methodology recognized and agreed upon by the Government of Indonesia in a consistent and reliable infrastructure. Conventional QTO data includes volumetric measurements of concrete and reinforcement weight for each component *of the bridge* abutment.

In the *bore pile* foundation work using payment item 7.6 (19a), a Concrete drill pyre, diameter 800mm, with volume calculation is "meter." The description of the material used can be seen in the contractor's Work Unit Price Analysis (AHSP), where the main materials used in the bore pile foundation for each foundation meter are listed, as can be seen in Table 2.

Table 3 compares the quantity take-off (QTO) for sand and concrete material between the contractor and BIM counts. Meanwhile, Table 4 compares the reinforcement weight for one abutment from contractor data (conventional calculation) with the QTO results of the reinforcement weight from Building Information Modeling (BIM).

Table 2. Analysis of Work Unit Price (AHSP) of *Bore Pile Foundations* per Meter

No.	Component	Unit	Estimated quantity	Unit Price	Total Price
1	Self-compacting concrete f 'c 30 MPa	M3	0.6032	2,751,538.73	1,659,689.06
2	Reinforcement Steel	Kg	72.3823	14,406.16	1,042,750.92

Table 3. Comparison of QTO of sand and concrete materials for 1 abutment

No.	Job Items	Material Volume (M3)		Unit Price (Rp./Kg)	Total Price (Rp.)	
		Contractor	BIM		Contractor	BIM
Selected Stacks from mineral sources						
1	Sand the working floor. 10cm	6.14	5.17	116,985.70	718,292.20	604,816.07
	Sub Total	*6.14*	*5.17*		*718,292.20*	*604,816.07*
Concrete, fc' 15 MPa						
1	Concrete working floor f 'c 15 MPa	6.14	5.17	1,584,588.93	9,729,376.03	8,192,324.77
	Sub Total	*6.14*	*5.17*		*9,729,376.03*	*8,192,324.77*
Concrete structure, f 'c 35 MPa						
1	Abt - Body	17.11	16.48	2,592,068.30	44,350,288.61	42,717,285.58
2	Abt - *Back wall*	10.45	10.83	2,592,068.30	27,087,113.74	28,072,099.69
3	Abt - *Wing wall*	13.10	12.38	2,592,068.30	33,956,094.73	32,089,805.55
4	Abt - Stepping Plate	12.00	11.66	2,592,068.30	31,104,819.60	30,223,516.38
5	Abbot - *Stopper*	0.69	0.66	2,592,068.30	1,788,527.13	1,710,765.08
6	Abbot – D. Ornamen	2.63	2.10	2,592,068.30	6,817,139.63	5,443,343.43
	Sub Total	*55.98*	*54.11*		*145,103,983.43*	*140,256,815.71*
Concrete of large volume structures, f'c 35 MPa						
1	Abt - *Footing*	69.60	68.65	2,575,652.40	179,265,407.04	176,818,537.26
2	Abt - Head	25.23	24.90	2,575,652.40	64,983,710.05	64,133,744.76
	Sub Total	*94.83*	*93.55*		*244,249,117.09*	*240,952,282.02*
Self-Compacted Concrete f 'c 30 MPa						
1	Bore Pile *Foundation*	130.29	107.04	2,751,538.73	358,501,282.98	294,524,705.66
	Sub Total	*130.29*	*107.04*		*358,501,282.98*	*294,524,705.66*
	Total				**758,302,051.73**	**684,530,944.23**

Table 4. Comparison of QTO reinforcement weight for 1 abutment

No.	Job Items	Rebate Weight (kg)		Unit Price (Rp./Kg)	Total price (Rp.)	
		Contractor	BIM		Contractor	BIM
Bore *Pile*						
1	Bore Pile *Foundation*	15,634.58	11,908.65	14,406.16	225,234,261.01	171,557,917.28
	Sub Total	*15,634.58*	*11,908.65*		*225,234,261.01*	*171,557,917.28*
BjTS 420A Fin Reinforcement Steel						
1	Abt – *Footing*	7,622.09	7,357.22	15,846.78	120,785,583.37	116,588,246.75
2	Abt – Body	7,792.52	7,441.99	15,846.78	123,486,350.09	117,931,578.29
3	Abt – Head	2,444.42	2,407.19	15,846.78	38,736,185.97	38,146,210.35
4	Abt - *Back wall*	1,564.48	1,595.13	15,846.78	24,791,970.37	25,277,674.18
5	Abt - *Wing wall*	3,505.09	1,755.18	15,846.78	55,544,390.11	27,813,951.32

6	Abt - Stepping Plate	2,677.88	2,642.88	15,846.78	42,435,775.23	41,881,137.93
7	Abbot - *Stopper*	161.64	162.03	15,846.78	2,561,473.52	2,567,653.76
8	Abbot - D. Ornaments	2,217.70	2,169.76	15,846.78	35,143,404.01	34,383,709.37
	Sub Total	*27,985.82*	*25,531.38*		*443,485,132.66*	*404,590,161.96*
	Total				**668,719,393.67**	**576,148,079.24**

After comprehensively summarizing conventional QTO and BIM-based QTO data with Autodesk Revit, the next phase involves evaluating the accuracy of QTO using MAPE. Conventional QTO data is a benchmark for Revit BIM QTO's accuracy. This comparative analysis aims to measure the variance between the two methodologies and provide insight into the effectiveness of the BIM approach in calculating material quantities compared to conventional methods. MAPE acts as a quantitative measure. This systematic approach contributes to the overall validity and reliability of the research findings. Table 5 presents the QTO accuracy values of sand and concrete, and Table 6 presents the QTO accuracy values of reinforcement using the MAPE approach.

Table 5. Test the accuracy of BIM Revit sand and concrete with MAPE

No.	Job Items	Volume Difference (M3)	Concrete QTO Accuracy (%)
Selected Stacks from mineral sources			
1	Urug sand working floor t.10cm	0.97	15.80
Concrete, fc' 15 MPa			
1	Concrete Working Floor fc' 15 Mpa t.10cm	0.97	15.80
Concrete structure, f 'c 35 MPa			
1	Abt - Body	0.63	3.68
2	Abt - *Back wall*	-0.38	-3.64
3	Abt - *Wing wall*	0.72	5.50
4	Abt - Stepping Plate	0.34	2.83
5	Abbot - *Stopper*	0.03	4.35
6	Abbot - D. Ornaments	0.53	20.15
Concrete of large volume structures, f'c 35 MPa			
1	Abt - *Footing*	0.95	1.36
2	Abt - Head	0.33	1.31
Self-Compacted Concrete f 'c 30 MPa			
1	Bore Pile *Foundation*	23.25	17.85
	MAP		**7.73**

Table 6. Reinforcement BIM Revit accuracy test with MAPE

No.	Job Items	Reinforcement Difference (kg)	Reinforcement QTO Accuracy (%)
Bore *Pile*			
1	Bore Pile *Foundation*	3,725.93	23.83
BjTS 420A Fin Reinforcement Steel			
1	Abt - *Footing*	264.87	3.48
2	Abt - Body	350.53	4.50
3	Abt - Head	37.23	1.52
4	Abt - *Backwall*	-30.65	-1.96

5	Abt - *Wing wall*	1,749.91	49.92
6	Abt - Stepping Plate	35.00	1.31
7	Abbot - *Stopper*	-0.39	-0.24
8	Abbot – D. Ornaments	47.94	2.16
	MAP		**9.39**

The analysis of the table above shows a significant difference in the calculation of sand and concrete materials, as well as reinforcing steel when using BIM Revit for QTO in the construction of one *abutment* of a bridge. In particular, there was a variance of 7.73% in sand and concrete materials, and 9.39% in reinforcing steel materials. This difference arises because several things, such as the conventional QTO calculation for materials, do not reduce the estimated volume of reinforcement, where if a reduction is made, it will reduce the volume of ±4.81 M3 of concrete and sand materials for one *abutment* only. However, the calculation is not simple if calculated manually because it must have accuracy and a long enough time to be done, so that in the technical specifications of the *owner of* the X bridge work, there is no provision to reduce the volume of concrete with the estimated volume of reinforcement.

This study adds the calculation of potential differences in the cost of sand and concrete materials and the reinforcing steel of the two QTO methods that have been carried out, significantly affecting the material cost and the overall feasibility of construction. From the results of the calculation above, it is found that the price difference between *the contractor's back up* calculation and Building Information Modeling (BIM) has a fairly significant difference value, namely IDR 166,342,421.94 (One hundred and sixty-six million three hundred and forty two thousand four hundred and twenty-one rupiah) or an *error* value11,66%. Calculations using BIM have a smaller price value than conventional calculations. These results can be used as a reference for the validation of conventional calculations carried out by contractors to avoid undesirable things in the future related to liability *claims* from material volume and price.

It can be seen that the difference in value that occurs is still within a reasonable limit, but several work items have *a significant difference in quantity take-off*. The following is a description of the difference in volume that occurs in sand and concrete materials in the abutment:

1. The choice of excavation sources for the sand work floor is 10cm in the heap work. The volume difference is due to the lack of a reduction in the volume of the bore pile foundation by 12 points and an increase in the length and width of the sand and concrete working floor by 0.2m, which produces a difference in QTO volume of 0.97 m3.
2. In concrete work, fc = 15 MPa for concrete work floor work.10cm The volume difference is due to no reduction in the volume of the *bore pile foundation* by 12 points and the addition of the length and width of the sand and concrete working floor by 0.2m. This produces a difference in QTO volume of 0.97 m3.
3. In the concrete work of the FC' 35 MPa structure, there are several descriptions:
   - Abutment—Body: There is a difference because calculating QTO with BIM reduces the volume of reinforcement, and there is a human error in calculating the contractor's data backup.

- Abutment—Back Wall: There is a difference because calculating QTO with BIM reduces the reinforcement volume, and there is human error in calculating backup contractor data.
- Abutment—Wingwall: There is a difference because the calculation of QTO with BIM reduces the volume of reinforcement.
- Abutment—Stepping Plate: There is a difference because the calculation of QTO with BIM reduces the volume of the reinforcement.
- Abutment—Stopper: There is a difference because the calculation of QTO with BIM reduces the volume of reinforcement.
- Abutment—D. Ornament: There is a difference because calculating QTO with BIM reduces the volume of reinforcement, and there is a human error in calculating backup contractor data.

4. In the concrete work of large volume structures, f' 35 MPa, there are several descriptions:
   - Abutment—Footing: There is a difference because the calculation of QTO with BIM reduces the volume of reinforcement.
   - Abutment—Head: There is a difference because the calculation of QTO with BIM reduces the volume of reinforcement.
5. In the self-compacting concrete work fc' 30 MPa which is part of the 800mm diameter concrete drill pile work has a significant volume difference caused by the calculation of the unit price of the work there is a reduction with a loss factor with a coefficient of 1.2, because the length of the foundation reaches 18m per pile and there are 12 foundation piles in 1 abutment so that the volume difference is very large reaching 17.85% based on MAPE.

Meanwhile, in the QTO of steel reinforcement, there are several notes, namely:

1. In the drill pile foundation, which has a payment type per meter, the calculation in the work cost budget plan is based on estimates. Suppose you look at the estimated weight of 120kg of reinforcement per m3 of concrete, resulting in a value of 72.38kg per m of bore pile foundation. In that case, this makes the calculation of steel reinforcement considerably different compared to the state installed in the field.
2. Human error occurs in the rebar steel for the wing wall abutment component, so the calculation of reinforcement on this component is repeated twice, resulting in a calculation that is twice the actual calculation.
3. Other abutment components such as footing, body, head, back wall, step plate, stopper, and ornament stand have a difference at a reasonable limit of <5% compared to the BIM QTO calculation. This difference occurs due to differences in the sum of the bending of the reinforcement, the total length of the reinforcement, and the number of rods of the abutment section.

CONCLUSION

The conclusions drawn from this study show a striking difference in accuracy between *quantity take-off* (QTO) using Autodesk Revit BIM and conventional QTO methods. The accuracy of QTO for sand and concrete components was recorded at 7.73%, while for steel reinforcement it was 9.39%. This difference can be attributed to various factors, especially in concrete materials that do not reduce the estimated reinforcement volume, because there are human limitations in calculating manually. Also, in the technical specifications of the owner, there is no provision to reduce the concrete volume with the estimated reinforcement volume, even though it significantly impacts the total concrete volume that must be paid. It can be seen that the use of technology such as BIM can be a source of volume validation to minimize *human error* that can harm project *stakeholders*.

As for steel reinforcement materials, there is a considerable difference in the calculation of *wing wall abutment* reinforcement, which is 1,749.91kg greater than BIM-based QTO. This occurs due to human error in conventional reinforcement calculations, causing double counting, which is, of course, very detrimental because it increases the weight of reinforcement much more significantly than it should.

This research provides important insights into the challenges and limitations associated with using BIM for quantity take-off, emphasizing the need to integrate nationally relevant standards to improve the accuracy of material quantity estimation in construction projects such as bridge work. Building Information Modeling (BIM) is not just *software*; it is a framework system for thinking in various stages of construction based on a 3D geometry model. The 3D model contains useful information at each stage of construction, so the construction process takes place more effectively and efficiently.

REFERENCES

Nope. (2020). Application of BIM for Project Scheduling System with 4D Model and 5D Cost Estimation. *Journal of Archicentre Architecture*, *3*(1).

Antunes, B. G. M. (2018). *Quantity Take-off in traditional and BIM environments: Comparative Analysis of Concrete and Formworks of Building Structures*.

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership Management*, *11*(3), 241–252.

De Myttenaere, A., Golden, B., Grand, B. Le, & Rossi, F. (2016). Mean Absolute Percentage Error for regression models. https://doi.org/10.1016/j.neucom.2015.12.114

Director General of Highways of the Ministry of PUPR. (2023). Guidelines for the Implementation of Building Information Modelling (BIM) in the Scope of Road and Bridge Construction Work. *JDIH Ministry of PUPR*.

Disney, O., Roupé, M., Johansson, M., Ris, J., & Höglin, P. (2023). TOTAL BIM ON THE CONSTRUCTION SITE: A DYNAMIC SINGLE SOURCE OF INFORMATION. *Journal of Information Technology in Construction*, *28*, 519–538. https://doi.org/10.36680/j.itcon.2023.027

Doloi, H. K. (2011). Understanding Stakeholders' Perspective of Cost Estimation in Project Management. *International Journal of Project Management*, *29*(5), 622–636. https://doi.org/10.1016/j.ijproman.2010.06.001

Gołaszewska, M., & Salamak, M. (2017). Challenges in Takeoffs and Cost Estimating in the BIM Technology, Based on the Example of a Road Bridge Model. *Czasopismo Techniczne*, *4/2017*, 1–10. https://doi.org/10.4467/2353737xct.17.048.6359

Herdyana, H., & Suroso, A. (2023). The impacts of 5D-Building Information Modeling on construction's Time and cost performance. *Sinergi (Indonesia)*, *27*(3). https://doi.org/10.22441/sinergi.2023.3.010

Igba Emmanuel, Edwin Osei Danquah, Emmanuel Adikwu Ukpoju, Jesutosin Obasa, Toyosi Motilola Olola, & Joy Onma Enyejo. (2024). Use of Building Information Modeling (BIM) to Improve Construction Management in the USA. *World Journal of Advanced Research and Reviews*, *23*(3), 1799–1813. https://doi.org/10.30574/wjarr.2024.23.3.2794

Inzerillo, L., Acuto, F., Pisciotta, A., Dunn, I., Mantalovas, K., Uddin, M. Z., & Di Mino, G. (2023). ISIM - INFRASTRUCTURES & STRUCTURES INFORMATION MODELING: A NEW CONCEPT OF BIM FOR INFRASTRUCTURES. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* (Vol. 48, pp. 49–56). International Society for Photogrammetry and Remote Sensing. https://doi.org/10.5194/isprs-archives-XLVIII-5-W2-2023-49-2023

Lubis, A. M., Rifai, A. I., Sari, Y. A., & Handayani, S. (2024). The Concept of Bridge Substructure Planning using Revit Application for BIM Approach. *Indonesian Journal of Multidisciplinary Science*, *3*(12), 1.

Muñoz-La Rivera, F., Vielma, J. C., Herrera, R. F., & Carvallo, J. (2019). Methodology for Building Information Modeling (BIM) Implementation in Structural Engineering Companies (SECs). *Advances in Civil Engineering*, *2019*. https://doi.org/10.1155/2019/8452461

Nafiyah, R., & Martina, N. (2022). Quanitity Takeoff Analysis on Bridge Understructure Work. *Construction and Material Journal*, *4 No. 2*, 1–10. Retrieved from http://jurnal.pnj.ac.id/index.php/cmj

Nan, C., Fenglong, K., Xin, W., Changtao, W., Ning, Q., Xiyang, L., ... Bin, W. (2016). Research on the Secondary Development of Revit Software. In *International Conference on Education, Management, Computer and Society*. Atlantis Press.

Nur Dhou, Y., & Susanto, A. (2023). Comparative Analysis of Calculations of Conventional Methods and Building Information Modelling (BIM) on Construction Work Volume and Cost. In *Proceedings of the 2023 National Seminar on Civil Engineering, Faculty of Engineering, UMS* (pp. 1–8). Surakarta, Central Java.

Ricardo, V. A., Rifai, A. I., Ginting, J. M., & Prasetijo, J. (2024). The Simulation of Bridge Pier Planning using Revit: A Building Information Modelling Approach. *Indonesian Journal of Multidisciplinary Science*, *3*(12), 1–0.

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). *BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers*. John Wiley & Sons.

Sadad, I., Hendi Jaya, F., & Januar, I. W. (2022). Implementation of BIM Take Off Quantity Material of Bridge Abutment Structure on Planned Volume. *Journal of Engineering Science*, *07*(2), 2022.

Samimpay, R., & Saghatforoush, E. (2020). Benefits of Implementing Building Information Modeling (BIM) in Infrastructure Projects. *Journal of Engineering, Project, and Production Management*, *10*(2), 123–140. https://doi.org/10.2478/jeppm-2020-0015

Sampaio, Alcinia Z., & Gomes, A. M. (2022). BIM Structural Project Applied in A Case Study: Interoperability Analyses, Reinforcement Detailing Drawings and Quantity Take-off. *The Open Construction & Building Technology Journal*, *15*(1), 196–213. https://doi.org/10.2174/1874836802115010196

Sampaio, Alcinia Zita, Sequeira, P., Gomes, A. M., & Sanchez-Lite, A. (2023). BIM Methodology in Structural Design: A Practical Case of Collaboration, Coordination, and Integration. *Buildings*, *13*(1). https://doi.org/10.3390/buildings13010031

Saputra, H., Pratama, R., Tita, E. E., & Yusa, M. (2024). Comparative Analysis of Quantity Take-Off Material Between Conventional Method & BIM Nemetschek Allplan Method on Bridge. *Civil Engineering and Architecture*, *12*(4), 2622–2633. https://doi.org/10.13189/cea.2024.120410

Shatalin, A. *DDCIV20 Double Degree in Civil and Construction Engineering Reinforcement design using SOFiSTiK in Revit*.

Simatupang, F. J., Hasibuan, G. C. R., Jaya, I., Syahrizal, Dewi, R. A., & Syafridon, G. G. A. (2024). Quantity Take Off Comparison Using Building Information Modelling (BIM) with Autodesk Revit Software and Traditional Method. *International Journal of Architecture and Urbanism*, *8*(2), 184–190. https://doi.org/10.32734/ijau.v8i2.16146

Singh, T., Mahmoodian, M., & Wang, S. (2025). Advancing Smart Construction Through BIM-Enabled Automation in Reinforced Concrete Slab Design. *Buildings*, *15*(3). https://doi.org/10.3390/buildings15030343

Whang, S.-W., & Min, S. (2016). Building Information Modeling (BIM) for Project Value: Quantity Take-Off of Building Frame Approach. *International Journal of Applied Engineering Research*, *11*, 7749–7757. Retrieved from http://www.ripublication.com

Yönder, V. M., & Çavka, H. B. (2024). A Case Study of Clash Detection for Early Design Phases in Building Information Modelling. *Livenarch+*, *1*, 1–5.

Zhang, J., Chen, M., Ballesteros-Pérez, P., Ke, Y., Gong, Z., & Ni, Q. (2023). A New Framework to Evaluate and Optimize Digital Transformation Policies in the Construction Industry: A China Case Study. *Journal of Building Engineering*, *70*(28 March 2023), 1–19. https://doi.org/10.1016/j.jobe.2023.106388

Zhang, S., Tang, Y., Zou, Y., Yang, H., Chen, Y., & Liang, J. (2024). Optimization of architectural design and construction with integrated BIM and PLM methodologies. *Scientific Reports*, *14*(1), 26153. https://doi.org/10.1038/s41598-024-75940-x

Zuo, W., Huan, G., Zhu, J., Chen, L., & Hong, X. (2020). Development and Application of Rebar Information Table Module Based on Revit Platform. In *IOP Conference Series: Earth and Environmental Science* (Vol. 567). IOP Publishing Ltd. https://doi.org/10.1088/1755-1315/567/1/012024