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Revit-Based QMTO Optimization for Efficiency in Sustainable Construction and Vocational Innovation Practices: A Case Study of the P2 Foundation of the Main Building of the KPwBI Office in Indonesia

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ABSTRACT

Structural work, particularly foundations, is a vital component in building construction projects that demands high accuracy in calculating material quantities. This research aims to optimize the Quantity Material Take-Off (QMTO) process for the P2 foundation type (1500 × 900 × 800 mm) by comparing conventional 2D drawing-based methods with digital methods using Building Information Modeling (BIM) through Autodesk Revit. The research method applied is Research and Development (R&D), which includes stages of data collection, planning, and 3D model development. The analysis results show that BIM Revit can generate more precise digital models and support automated and verifiable QMTO processes. The concrete volume discrepancy between the conventional and Revit methods is −0.180 m³ (−0.926%), the rebar difference is +2066.040 kg (+229.293%), while the number of pile points remains identical. Technical evaluation proves that Revit is capable of detecting actual geometry and detailed structural configurations comprehensively, resulting in more accurate quantity data. The implementation of Autodesk Revit-based BIM has been proven to improve efficiency, material estimation accuracy, and data reliability in structural foundation planning while also supporting the achievement of the Sustainable Development Goals (SDGs), particularly SDG 9 (industry and infrastructure innovation), SDG 11 (resilient and sustainable construction), and SDG 12 (efficient and responsible material consumption), through automated calculations, error reduction, and transparency of construction material data.

INTODUCTION

In building construction projects, structural works are crucial elements that determine the overall stability and safety of the structure. One of the main components in the substructure system is the foundation, which functions to distribute building loads evenly and safely to the supporting soil. Accuracy in calculating foundation materials such as concrete, rebar, and pile point quantities significantly affects the accuracy of cost estimates and the efficiency of material procurement planning (Subakti, 2019). Efficient use of construction materials is one of the key indicators in supporting sustainable development, in line with the Sustainable Development Goals (SDGs).

The conventional Quantity Material Take-Off (QMTO) process is generally performed through the interpretation of 2D technical drawings, followed by manual or semi-manual calculations using spreadsheets. While this method has long been used in various projects, it has fundamental weaknesses such as potential errors in reading drawings, data inconsistency, and difficulty in tracking design revisions (Sacks et al., 2018). Quantification errors in foundation elements can lead to overordering materials, structural work delays, and resource waste, which contradicts the principle of material efficiency in sustainable construction.

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With the advancement of digital technology in the construction sector, Building Information Modeling (BIM) has emerged as a system capable of integrating geometric and non-geometric data into a single parametric and dynamic 3D model. Autodesk Revit, as a widely used BIM platform, allows for accurate structural modeling, early clash detection between elements, and automatic, documented material quantity extraction. BIM not only improves the productivity of design processes and interdisciplinary coordination but also provides more accurate and traceable QMTO data, supporting data-driven decision-making in construction project management (Eastman et al., 2011).
In the context of material efficiency and construction waste reduction, BIM implementation contributes to achieving the Sustainable Development Goals, particularly SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 12 (Responsible Consumption and Production). By providing accurate and real-time quantitative information, BIM supports better decision-making in material procurement and project adaptability while minimizing unnecessary structural material waste.
This study aims to analyze the effectiveness of Autodesk Revit as a BIM tool in optimizing the Quantity Material Take-Off (QMTO) process for the P2 foundation element measuring 1500 × 900 × 800 mm. The study uses the Main Building of the Temporary Representative Office of Bank Indonesia (KPwBI) Tegal as a case study. Evaluation is carried out by comparing material quantity outputs between the conventional 2D-based method and the digital BIM-based approach. The parameters analyzed include concrete volume, rebar weight, and the number of pile points, along with time efficiency, data accuracy, and potential quantity deviation. The findings are expected to provide practical contributions to BIM technology integration for improving structural planning and sustainable material resource management.

METHOD

This study uses the Research and Development (R&D) method. Based on the development model of Gall & Borg (1983), there are ten stages, but in this study, only three stages are applied: research and data collection, planning, and development. These are described as follows:

1. Research and Data Collection
   This stage focuses on gathering information about the application of Autodesk Revit BIM and QMTO through interviews and literature reviews on the KPwBI Tegal building project.
2. Planning
   In this stage, the researcher formulates the required competencies and establishes objectives to evaluate the effectiveness of BIM in material quantity estimation.
3. Development
   The researcher develops a 3D model using Autodesk Revit and prepares evaluation instruments to assess the BIM and QMTO implementation.

RESULT AND DISCUSSION

1. Research and Data Collection

This research focuses on the Main Building of the Temporary Office of the Bank Indonesia Representative Office (KPwBI) in Tegal. The initial phase included a literature review on the application of Autodesk Revit in QMTO structural work, identification of research needs, preliminary studies, and the development of a conceptual and methodological framework. Data collected included general building data, technical data, planning drawings, and installed material requirements.

2. Planning

Planning is the process of setting goals and selecting courses of action to achieve them. It includes situation analysis, goal setting, and developing alternatives. Effective planning must be flexible to adapt to environmental changes. Here are some steps involved:

2.1 3D Modelling Shopdrawing

The scope of structural elements modeled includes the P2 foundation (1500 × 900 × 800 mm) with precast piles ⌀250 × 250 mm used in the Main Building of the KPwBI project in Tegal.

2.2 3D Modelling Parameters

3D modeling of the P2 foundation in Autodesk Revit is based on 2D shop drawings as the primary reference. These drawings are imported into Revit and used to build an accurate digital model. The main input parameters include:

1. Gridlines – To determine the horizontal and vertical positions of structural elements
2. Floor Levels – To define elevation differences between levels
3. Building Dimensions – To define the overall size of the structure
4. Structural Element Dimensions – For the specific sizing of the foundation

These parameters are configured using Revit's Type Properties and Instance Parameters. This approach produces a 3D model that is accurate, informative, and ready for technical analysis and material quantification (QMTO).

3. Development

In this development stage, 3D structural modeling was performed using Autodesk Revit and the output results from the Quantity Material Take-Off (QMTO) process were analyzed using Autodesk Revit and the differences between the output results and the conventional method. The following are some of the steps taken:

3.1 3D Structural Modeling

The 3D model of the shop drawings is constructed based on the technical specifications of each structural element as outlined in design documents and planning data. The following figures illustrate the resulting model:

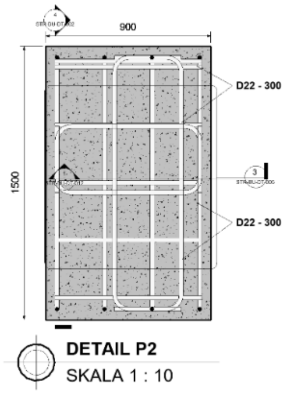

Figure 1. Detail of Foundation
P2 – 1500 × 900 × 800 mm
Source: Personal Data, 2025

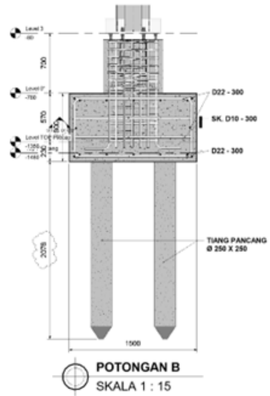

Figure 2. Section B of Foundation
P2 – 1500 × 900 × 800 mm
Source: Personal Data, 2025

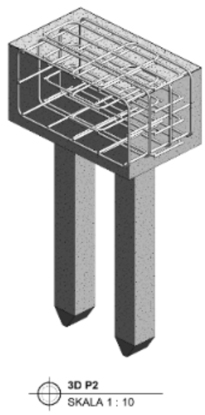

Figure 3. 3D Model of Foundation P2 1500 X 900 X 800
Source: Personal Data, 2025

3.2 Model Verification and Validation

3.2.1 Geometry and Detailing Inspection of P2 Foundation Structure

This phase verifies several aspects:

a.) Structural element dimensions (length, width, thickness)
b.) Elevation and coordinates of elements for level conformity
c.) Orientation and joint connections between structural components
d.) Rebar detailing including diameter, quantity, shape, and layout (main and shear reinforcement)

This verification ensures the model is complete and accurate enough to be used for reliable material quantity analysis.

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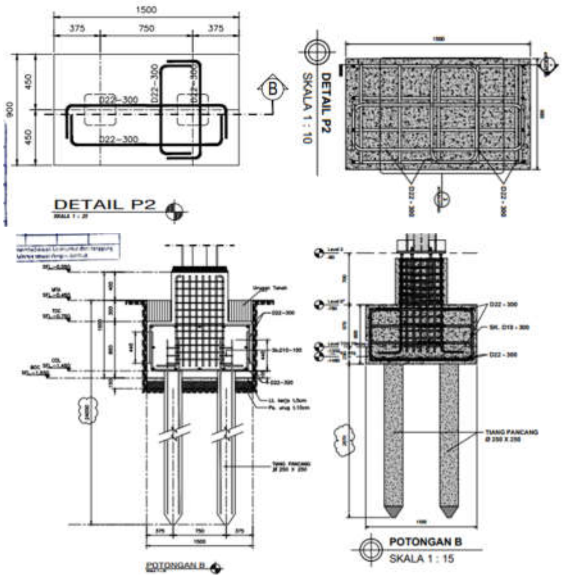

Figure 4. Verification P2 1500 X 900 X 800
Source: Personal Data, 2025

3.2.2 Validation of Quantity Volume of Structural Elements of Foundation P2

Structural element volume validation is performed to ensure that the Quantity Material Take-Off (QMTO) results generated through BIM models, particularly using Autodesk Revit, maintain a reliable level of technical accuracy. This process involves comparing the volumes of each structural component, such as foundations, columns, and beams, obtained from the 3D model, with conventional calculations based on 2D engineering drawings.

According to Pauwels et al. (2024), the rule-based model checking approach has become an important method for verifying BIM data quality because it allows for the detection of volume discrepancies down to the individual structural element level. This ensures that the model meets technical standards before being used for the next analysis stage.

In practice, validation in this subsection begins by extracting volume data from Revit using the Schedule/Quantities feature, which is then compared with manual estimates.

Table 1. Validation of Foundation Volume P2 1500 X 900 X 800 Main Building

Validation of the P2 Foundation Volume of the Main Building					
No.	**Type**	**Total**	**Items**	**Conventional Volume**	**Revit Volume**
A	**Foundation Volume Validation**				
1	P2 = 1500 X 900 X 800	18	Concrete (m^3)	19,440	19,260
			Iron (kg)	901,440	2967,480
			Pile (point)	36,000	36,000

Source: Personal Data, 2025

3.3 Quantification and Comparison Results

3.3.1 Output results from the Quantity Material Take-Off (QMTO) process carried out using Autodesk Revit

The following is the QMTO output for the P2 1500 X 900 X 800 foundation for the construction project of the Temporary Building of the Bank Indonesia Representative Office (KPwBI) Tegal, namely:

1.1 Quantity Material Take-Off Concrete Foundation P2			
Family and Type	Level	Area	Volume
M_Footing-Rectangular: P2 = 1500 X 900 X 800			
M_Footing-Rectangular: P2 = 1500 X 900 X 800	Level 0"	1 m²	19.22 m³
Grand total			19.22 m³

QUANTITY MATERIAL TAKE-OFF CONCRETE FOUNDATION P2

Figure 5. Quantity Material Take-Off Concrete Foundation P2
Source: Personal Data, 2025

6.1 Quantity Material Take-Off Rebar Foundation P2						
Host Mark	Bar Diameter	Total Bar Length	Bar Length	Reinforcement Volume	Unit Weight	Total Weight
19 mm						
P2 = 1500 X 900 X 800	76 mm	37240 mm	6115 mm	10670.05 cm³	2.25 kg/m	83.79 kg
22 mm						
P2 = 1500 X 900 X 800	3996 mm	967680 mm	256118 mm	374565.35 cm³	2.98 kg/m	2883.69 kg
Grand total	4072 mm	1004920 mm	262233 mm	385235.39 cm³		2967.48 kg

QUANTITY MATERIAL TAKE-OFF REBAR FOUNDATION P2

Figure 6 Quantity Material Take-Off Rebar Foundation P2
Source: Personal Data, 2025

1.1 Quantity Material Take-Off Pile P2	
Mark	Count
Pile P2	
Pile P2	36
Grand total	36

QUANTITY MATERIAL TAKE-OFF PILE P2

Figure 7 Quantity Material Take-Off Piles P2
Source: Personal Data, 2025

3.3.2 Difference in Output Results from the Quantity Material Take-Off (QMTO) process for structural work between the Autodesk Revit method and the conventional method

The results of the validation of the volume of structural elements in the P2 foundation of the main building show a difference between the conventional method and the Building Information Modeling (BIM)-based method using Autodesk Revit. For the concrete elements, the volume obtained using the conventional method was 19,440 m³, while the calculation using Autodesk Revit showed a volume of 19,260 m³. This difference is -0.180 m³, or approximately -0.926%, which is still within technical tolerances and acceptable in construction practice.

For the reinforcing steel elements, the volume difference is very significant. The conventional method resulted in a total weight of 901,440 kg, while the calculation using Revit resulted in a result of 2,967,480 kg. The difference between the two is 2,066,040 kg, representing a deviation of 229.293%. This large difference indicates different assumptions in the calculation method, possible differences in input units, the level of detail of the reinforcement modeling in Revit, or the omission of waste and splice factor weighting in the conventional method. Meanwhile, for the pile element, both the conventional and Revit methods produced an identical number of points, namely 36, with no difference or deviation (0%).

Table 2 Comparison Results of the Output Volume of the P2 1500 X 900 X 800 Foundation in the Conventional Method and the Revit Method for the Main Building of the Temporary Building Construction Project for the Bank Indonesia Representative Office (KPwBI) Tegal

Comparison Results of Volume Output of Conventional and Revit Method							
No.	**Type**	**Quantity**	**Unit**	**Conventional Volume**	**Revit Volume**	**Difference**	**Difference (%)**
				a	**b**	**c = b - a**	**d = c : a**
A	**Foundation Volume Validation Comparison**						
1	P2 = 1500 X 900 X 800	18	Concrete (m³)	19,440	19,260	-0,220	-1,132%
			Iron (kg)	901,440	2967,480	2066,040	229,193%
			Pile (point)	36,000	36,000	0,000	0,000%

Source: Personal Data, 2025

Description:

(pink)	:	The difference is greater than the conventional method
(green)	:	There is no difference between the two calculation methods
(yellow)	:	The bigger difference of BIM Revit method

3.3.3 Technical Evaluation of Differences in Quantity Material Take-Off (QMTO) Results for Structural Work Using Autodesk Revit and the Conventional Method

The evaluation was conducted on 18 P2 type foundation elements (1500 × 900 × 800) in the Main Building. A comparison was made between the conventional 2D-based method and the BIM modeling method using Autodesk Revit.

1. Concrete
   A negative difference of -0.220 m^3 (-1.132%) indicates that Autodesk Revit calculated the concrete volume by considering the actual net geometry (net volume), while the conventional method tended to overestimate the volume due to the as-to-as dimension approach and did not consider voids or overlaps.
2. Reinforcement
   There was a significant increase of +2,066,040 kg (+229.193%) in the Revit results compared to the conventional method. This is due to Revit's ability to detect all reinforcement elements in detail, including effective length, number of stirrups, hooks, and overlapping, which are often not calculated in detail in manual methods.
3. Pile Points
   The number of pile points yields identical results because the calculation of this element is usually modular and directly readable from the working drawings. Therefore, both conventional and BIM methods produce the same values.

CONCLUSION

This study demonstrates that BIM-based Quantity Material Take-Off (QMTO) with Autodesk Revit can improve the accuracy of material quantity estimation for structural foundation work. For type P2 foundations, the difference between the conventional method and BIM was recorded at -0.220 m^3 (-1.132%) for concrete and +2,066,040 kg (+229.193%) for reinforcement, with the same number of piles.

These results confirm the superiority of BIM in capturing detailed structural geometry and automatically generating verified quantity data. This approach is not only technically efficient but also supports sustainable construction by reducing estimation errors, potential material waste, and improving data traceability. BIM implementation aligns with SDGs 9 (Innovation and Infrastructure), SDGs 11 (Sustainable Cities), and SDGs 12 (Responsible Consumption and Production).

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