

Comparison of Building Information Modeling and Conventional Methods for Concrete and Rebar Quantity Take-Off

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ABSTRACT

Calculation of Quantity Take-Off (QTO) of concrete and rebar must be carried out accurately and consistently. Design modeling also often changes so that technology is needed to simplify and speed up work. The application of Building Information Modeling (BIM) is one way to reduce errors and speed up QTO calculations. One of the BIM software that can be used to carry out QTO work for concrete and rebar is Revit, which is produced by the Autodesk company. The use of Revit is still often encountered obstacles, but these obstacles can be anticipated by conducting an analysis. The analysis carried out include comparative analysis of calculation results, analysis of initial design time requirements and analysis time requirements if there is a design change, and analysis of advantages and obstacles in using Revit. The data was obtained by conducting interviews and calculating the QTO of concrete and rebar using Revit and conventional methods. The results show that the use of Revit is recommended. This is because Revit can speed up the calculation time for the QTO of concrete up to 49% and the QTO of rebar up to 20% for the initial design stage, the calculation of QTO of concrete if there is a design change up to 90%, and QTO of rebar up to 67% when compared to the conventional method. Respondents also stated that they prefer using the Revit method compared to conventional methods. This study shows that there are no difference results for the QTO of concrete and there is a slight difference for the QTO of rebar up to 0.6742%.

INTRODUCTION

Quantity Take-Off (QTO) is an important part of the construction process and is carried out by general contractors, subcontractors, cost consultants, and quantity surveyors. The task includes measuring and calculating the use of materials in a construction project to determine the materials, tools, equipment, and total labor usage required. According to Soeharto (2001), QTO is making a cost estimate by measuring the quantity of project components from drawings, specifications, and plans. Currently, many construction service providers are still using conventional methods in calculating QTO, while volume often changes due to design changes and these calculations must be carried out accurately and consistently. In performing QTO calculations, Cost Engineers often experience errors in calculations and the calculation process takes longer unintegrated drawings, quantities, schedules and costs in the use of conventional methods, especially when there is a design change. Technology that can increase productivity and quality is needed in the construction world. Building Information Modeling (BIM) could be one such technology.

According to Gegana (2020) in his book entitled Autodesk Revit – Collection, BIM is a process

in which various parties use various tools to create and process models and building information. There are dozens of software with different functions to support this BIM process to form a workflow for exchanging 3D models and data. One of the BIM software that can be used to generate QTO is Autodesk Revit. Autodesk Revit is a design program that can be used to follow the architect's mindset in all stages of design, from pre-design, schematic design, design development,

to construction documents (Gegana, 2020). Autodesk Revit is one of the BIM Design Authoring Software. BIM Design Authoring Software is the main BIM software which is defined as BIM software that is able to create BIM models starting from object based (3D geometry) along with all the information embedded in it. The results of this BIM model can later be used in other applications to extract geometry and information as needed. This software can design buildings and structures by modeling them in 3D while presenting working drawings in 2D and able to analyze QTO (5D) in each work item.

Many state-owned contractors and private contractors still doubt the accuracy of the calculations and the profits generated when performing QTO calculations using the BIM method. State-owned contractors and private contractors are also still questioning whether there is a difference in calculation result between the BIM method and the conventional method and what causes the difference in the calculation. Several obstacles are also often experienced by companies that have tried to use the BIM method and ignorance to avoid or overcome these obstacles makes the implementation of BIM look difficult and ineffective. This study was conducted to answer the problems that occurred.

In calculating the QTO of concrete and rebar in this study, the long span concrete box girder is used. The length of the western side span of 80 meters, the middle span of 120 meters, and the east side span of 80 meters. This structure is the longest span with a high level of complexity because it has a different structure for each span. This study was conducted to prove the accuracy of the results of QTO calculations using BIM, to overcome or avoid obstacles that might occur while using Revit, and the calculation for QTO of concrete and rebar of initial design time requirements and for QTO of concrete and rebar of time requirements if there is a design change. Based on the problems studied, this study aims:

1. Comparing the results of calculating the QTO of concrete and rebar requirements using the BIM method and conventional methods.
2. Comparing the time required to work on the QTO of concrete and rebar using the BIM method and conventional methods.
3. Comparing the time required to work on the QTO of concrete and rebar using the BIM method and conventional methods if there is a design change.
4. Identifying the advantages and obstacles encountered while using Revit in calculating QTO.

RESEARCH METHODS

In this study, the project under study is the JORR Elevated Toll Road Construction Project. It performs quantity calculations using 2 methods, namely the conventional method and the BIM method with Autodesk Revit software. This study combines two methods, namely quantitative and qualitative methods, so it is called mixed methods. The quantitative data used in this study is the difference in the QTO of concrete and rebar requirements using the BIM method and

conventional methods and calculating the time difference to calculate the concrete and rebar requirements in QTO work between the BIM method and the conventional method. Other quantitative data is to measure the difference in time required to calculate QTO in case of design changes using the BIM method and conventional methods. From the description above, the supporting data needed are detailed project drawings. In this study, the BIM method was carried out using Autodesk Revit software. In the study of concrete requirements, calculations were carried out on all spans of concrete box girder with a span length on the west and east sides of 80m and the middle side of 120 meters (Figure 1). The structure with the longest span in the JORR Elevated Toll Road Construction project. The rebar requirement is carried out in one segment which is the 1S5 segment (Figure 2) which is in the span of 80 meters. Qualitative data was obtained by conducting a simple interview with one of the BIM Development from a State-owned contractor company and a Private contractor company to find out the advantages and obstacles that are often experienced in applying the Revit method in several projects.

- **The Comparison of Concrete and Rebar Requirements**
Before calculating the QTO, the BIM Engineer and the Cost Engineer discussed with each other to adjust the QTO format to make it easier to check. After completing the calculations and obtaining the QTO of concrete and rebar, the value of the quantity of concrete is obtained in cubic meters (m^3) and the quantity of rebar in kilograms (Kg). The QTO obtained from the two methods will be reviewed for the difference in the results of quantity. If there is a difference in the calculation results, an analysis will be carried out and the percentage difference will be calculated.
- **The Time Requirements for the QTO of Concrete and Rebar of Initial Design**
This study was conducted by three BIM Engineers and three Cost Engineers with the same experience.
- **The Time Requirements for the QTO of Concrete and Rebar If There is a Change in Design**
The comparison of the time needed to calculate the QTO of concrete and rebar if there is a design change using the BIM method and the conventional method. This study was conducted by three BIM Engineers and three Cost Engineers with the same experience.
- **Identification of Advantages and Obstacles in Using Revit**
This study was conducted by collecting the advantages and obstacles that are often experienced when using BIM with Autodesk Revit software in State-owned contractors and Private contractors by conducting interviews with one of BIM Development person in a State-owned and Private contractor company. The results of the interviews were collected and conclusions were drawn about the advantages and obstacles experienced by the two companies. Obstacles resulting from the interview will be used to avoid obstacles that may be experienced during QTO work by the BIM Engineer.

**FIGURE 1. Cross Section Span
80m-120m-80m**

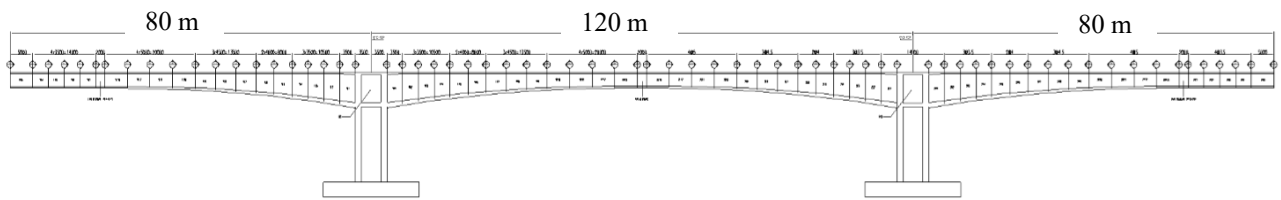
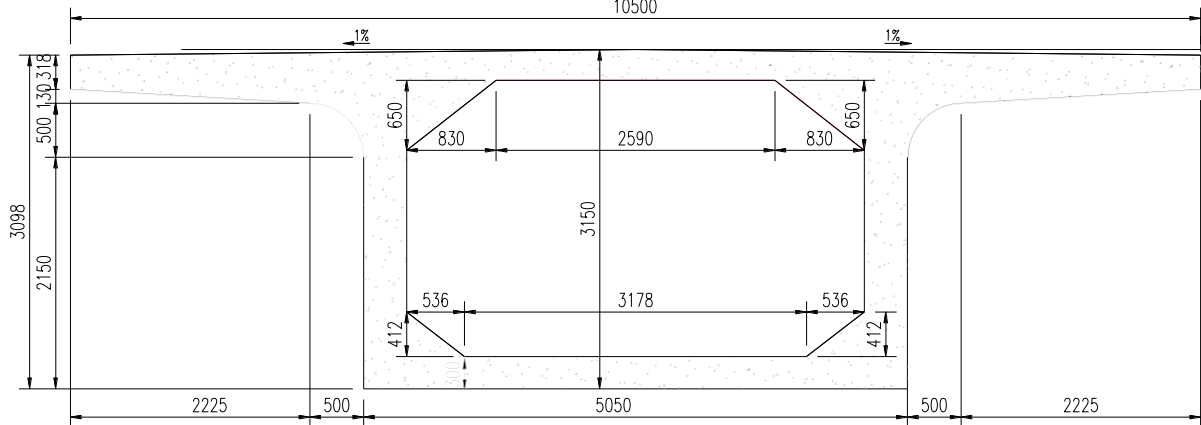


FIGURE 2. Detail Girder 1S5



RESULT AND DISCUSSION

1. The Comparison of Concrete and Rebar Requirements

• The Comparison of Concrete Requirements

Calculations were carried out on all 80m-120m-80m box girder segments. The total results of the comparison for the QTO of concrete using the conventional method and the BIM method were obtained and presented at Table 1 below:

**TABLE 1. The Comparison for the
QTO of Concrete**

Method	Quantity (m ³)	Quantity
Conventional	2672.7987	100
BIM	2672.7800	99.9993

Based on Table 1 above, it can be said that there is no difference in the calculation results because it is only 0.0007%. This is because differences in the use of the number of digits to the right of a decimal point. The BIM method uses three digits after the number of digits to the right of a decimal point, while the conventional method takes into account all the numbers after the number of digits to the right of a decimal point. This difference can be avoided by equating the use of the number of digits after the number of digits to the right of a decimal point.

1 The Comparison of Rebar Requirements

Calculations were made on the 1S5 segment in the 80m span so that the results of the comparison of rebar requirements using the conventional method and the BIM method were obtained and presented at Table 2 below:

TABLE 2. The Comparison for QTO of Rebar of Segments 1S5

Method	Quantity	Quantity
Conventional	7231.7499	100
BIM	7182.9954	99.3258

Based on Table 2 above, there is a slight difference of 0.6742% because when using the BIM method, the bending in the rebar is calculated curvilinearly, while in the conventional method the bending in the rebar is calculated perpendicularly. The BIM method calculates the total length of rebar but does not calculate the weight of rebar automatically. In calculating the weight of rebar in revit, it is done by adding columns and formulas manually as in Ms. Excel.

2. The Time Requirements for the QTO of Concrete and Rebar of Initial Design

In the study of the time requirement for calculating the quantity of concrete, it is carried out by counting all segments of the box girder span of 80m-120m-80m, while the quantity of rebar is carried out by calculating 1 segment of the box girder, namely the 1S5 segment in the span of 80m. This study was conducted by comparing the time required to calculate the QTO carried out by three BIM Engineers and three Cost Engineers.

- The Time Requirements for the QTO of Concrete of Initial Design

Calculations were carried out on all segments of box girder with span 80m-120m-80m which have a total volume of 2672.8 m³ and the results were obtained and presented at Table 3 below:

TABLE 3. Results of The Time Requirement for The QTO of Concrete of Initial Design

No	Name	Working Method	Time Requirement (Minutes)	Average Time (Minutes)	Average Time (%)
1	FGA	Conventional	147	167	100
2	VBY	Conventional	165		
3	DDE	Conventional	190		
4	SLM	BIM	91	86	51
5	ANM	BIM	85		
6	ALN	BIM	82		

- The Time Requirements for the QTO of Rebar of Initial Design
Calculations were made on the 1S5 segment contained in a span of 80m which has a total quantity using the conventional method of 7231.7499 Kg, while for the quantity using the BIM method of 7182.9954 Kg. The results were obtained and presented at Table 4 below:

TABLE 4. Results of The Time Requirement for The QTO of Rebar Initial Design

No	Name	Working Method	Time Requirement (Minutes)	Average Time (Minutes)	Average Time (%)
1.	FGA	Conventional	83	93	100
2.	VBY	Conventional	101		
3.	DDE	Conventional	96		
4.	SLM	BIM	81	75	80
5.	ANM	BIM	70		
6.	ALN	BIM	74		

Based on Tables 3 and 4 above, shows that the BIM method can speed up the process of calculating the QTO of concrete and rebar. BIM method can also provide three outputs namely shop drawings, 3D modelling, and quantity.

3. The Time Requirements for the QTO of Concrete and Rebar if There is a Change in Design
Design changes occur in the height increase of the entire box girder segment spans 80m-120m-80m of 500 mm. In this study, the calculation of the QTO of concrete if there is a change, is carried out on all box girder segments with a span of 80m-120m-80m, while for the QTO of rebar it carried out in the 1S5 segment which changes in length and amount of rebar due to changes in girder height. This study was conducted by comparing the time required to calculate the QTO carried out by three BIM Engineers and three Cost Engineers.

- The Time Requirements for the QTO of Concrete if There is a Change in Design
Calculations are performed on all segments of the box girder on a span of 80m-120m-80m which has a

height increase change of 500 mm in each segment and has a total volume of 2790.3 m³.
The results were obtained and presented at Table 5 below:

TABLE 5. Result of Time Requirement for The QTO of Concrete if There is a Design Change

No	Name	Working Method	Time Requirement (Minutes)	Average Time (Minutes)	Average Time (%)
1	FGA	Conventional	82	90	100
2	VBV	Conventional	92		
3	DDE	Conventional	95		
4	SLM	BIM	8	9	10
5	ANM	BIM	10		
6	ALN	BIM	9		

Based on Table 5 above, there is a big difference in time requirement because when a design change occurs using conventional method, the Cost Engineer needs to re-enter the volume changes that occur into Ms. Excel format and enter the images into the format one by one. It is the same as doing a re- calculation from scratch. In the BIM method, only entering one typical data segment that has changed, then the typical segment will change automatically.

- The Time Requirements for the QTO of Rebar if There is a Change in Design
Calculations were made on the 1S5 segment in the 80m span. There was a change in the amount of rebar and the length of the rebar because of the increase in segment height of 500 mm which has a total quantity of 7503.1756 Kg using the conventional method and 7454.3801 Kg using the BIM method. The results were obtained and presented at Table 6 below:

TABLE 6. Time Requirement for The QTO of Rebar if There is a Design Change

NO	NAME	WORKING METHOD	TIME REQUIRMENT (MINUTES)	AVERAGE TIME (MINUTES)	AVERAGE TIME (%)
1	FGA	Conventional	15		
2	VBY	Conventional	21	21	100
3	DDE	Conventional	27		
4	SLM	BIM	7		
5	ANM	BIM	6	7	33
6	ALN	BIM	8		

Based on the results above, the BIM method using Autodesk Revit software really helps speed up the QTO calculation process if there is a design change. This is in accordance with the name of Revit which stands for Revise Instantly.

4. Identification of Advantages and Obstacles in Using Revit

The result of the interviews with the two respondents were compile, then analyzed for similarities between the results of the opinions. Several advantages and obstacles were also encountered during the study process.

- Interviews Results from Two Respondents There are nine advantages in using Revit:
 - Calculations are more accurate and detailed
 - Reduced project costs
 - Have 3D visuals
 - Processing time becomes faster
 - Information on the user interface is complete, detailed, and easy to understand
 - There is no limitation of structural elements
 - Easy communication and integration
 - Easy to connect between Autodesk software
 - Reduce time and effort needed to revise design

There are five obstacles in using Revit:

- Requires hardware and software which is quite expensive in the initial investment
- The Family template available, especially for the infrastructure structure is incomplete
- Difficult to modelling the grid
- Not easy for new users to understand and use
- Template family is not found on the toolbar

- Result from the Study Process

There are two advantages in using Revit:

- Simplify the calculation of rebar, the distance between rebar is calculated automatically.
- Simplify QTO calculations especially for complex structures.

There are two obstacles in using Revit:

- Unable to produce rebar weight automatically.
- Unable to produce rebar shape.

CONCLUSION

Based on the results of the study, the following conclusions can be drawn:

1. Comparison of Concrete and Rebar Requirements

The results of the calculation of the QTO of concrete and rebar using the BIM method are accurate.

- Comparison of Concrete Requirements

There is no difference in the calculation result between the BIM method and the conventional method because it is only 0.0007% which was caused by the difference in the use of the number of digits to the right of a decimal point.

- Comparison of Rebar Requirements

It was found that the difference in the results of rebar requirements between the BIM method and the conventional method was 0.6742% because when using the BIM method, the bending in the rebar is calculated for curvilinearly, while in the conventional method the bending in the rebar is calculated perpendicularly.

2. Comparison of Time Requirements for QTO of Concrete and Rebar

The time required to calculate the quantity of concrete and rebar using the BIM method is faster than the conventional method. The BIM method using Revit software can speed up the process of working on the QTO of concrete and rebar with a percentage up to 49% for the calculation of the QTO of concrete and up to 20% for the calculation of the QTO of rebar.

3. Comparison of Time Requirements for QTO of Concrete and Rebar if There is a Design Change

The BIM method is very helpful in accelerating the process of calculating the QTO of

concrete and rebar if there is a design change a percentage in the calculation of the QTO of concrete by 90% and 67% in the calculation of the QTO of rebar.

4. Advantages and Obstacles in Using Revit

- Advantages:
 - Calculations are more accurate and detailed
 - Processing time becomes faster
 - There is no limitation of structural elements
 - Reduce time and effort needed to revise design
 - Simplify QTO calculations especially for complex structures

5. Obstacles:

- Requires hardware and software which is quite expensive in the initial investment
- Difficult to modelling the grid
- Unable to produce rebar weight automatically
- Unable to produce rebar shape.

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