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Comparative Analysis of Conventional Methods with BIM Methods on Construction Cost Estimate at Structure Project Design Calculations (Case Study of Construction of A Satpol PP Building)

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Abstract: Construction cost estimate in construction projects requires high accuracy in calculating work volumes and applying unit cost analysis. Lack of accuracy in calculating the volume of work can result in inaccurate cost estimates, causing project budget overruns. This research discusses the use of 3D BIM planning concepts using Autodesk Revit software to help calculate volumes accurately, with the aim of reducing project budget overruns. Comparative analysis of cost estimates between the use of Autodesk Revit and conventional methods provides an overview of the efficiency and effectiveness of using BIM software in estimating construction project costs. The object of this research is the Satpol PP Bantul office construction project, with a focus on structural work. This research method includes data collection, 3D BIM modeling, calculating cost estimates based on the volume produced using unit cost analysis, and comparative analysis of cost estimates between the use of BIM software and conventional methods. Based on the research results, it found that the construction cost estimate for structural work from Revit had a value of IDR 862,330,518.59 and a difference of IDR 53,420,195.31. This shows that the use of the 3D BIM concept results in 5.83% cheaper calculations than conventional construction cost estimate methods.

Keywords: Building Information Modeling, Construction Cost Estimate, Revit, Structure

Introduction

Digital technology nowadays is evolving at a rapid pace keeping up with the times. In an era like this most of people in the world have been integrated with technology that already existed. This technological advancement is very helpful for human life and has lots of impact. One of the impacts is that it allows infrastructure development to be faster and be more efficient. Building Information Modeling (BIM) is a method, system, or management of a work that is planned and projected in 3-dimensional modeling and contains information on planning, design, implementation, control, and maintenance that can be integrated with stakeholders (owners, consultants, contractors) (Li, 2024; Ojeda, 2024). Autodesk Revit is one of the software that has adopted the BIM system. Autodesk Revit users can design and plan a construction building project, both architectural, structural and MEP in 3D, 4D, and 5D (Liu, 2024; Porwal, 2023).

Cost calculation on a construction project is very sensitive and essential, this cost would become a main consideration in the implementation on a project. In implementing a project, cost planning requires high accuracy in calculating the volume of a work and analyzing the unit costs (Abdel-Hamid, 2023; Son, 2023). Lack of accuracy when calculating the volume of work will cause the estimated implementation cost to be very high and would cause waste of materials that cannot be utilized anymore and become a building waste. BIM method is still rarely used in Indonesia. This method is usually more often being used by a large scale companies with tall building projects because the Construction Estimate Plan that produced by large project is very crucial. BIM method is very helpful for large project in calculating Quantity Take Off with a high accuracy (Leite, 2023; Rodrigues, 2023).

This research discusses the application of the 3D BIM planning concept to structural work in a small-scale project located in the Satpol PP Building Construction Project using the 2022 version of Autodesk Revit software, to obtain the result of quantity take off that can reduce the remaining material from the project under review so that the construction estimate plan (BEP) does not swell (Ghorbany, 2023; Mollaei, 2023). In the analysis of cost estimation using Autodesk Revit which is compared with conventional calculations and provides an overview to the public by using software that implements BIM more efficiently and effectively in calculating the work volume, minimizing material waste and estimating cost in structural work.

Methodology

This research was conducted at the Satpol PP Building Construction Project in Bantul Regional Office Complex II, East Circle Manding St., Trirenggo, Bantul, D.I Yogyakarta, which has a building area of 984 m2 and a land area of approximately 2618 m2 as shown in Figure 1. This project has various types of rooms, but this research is only limited to a certain structures in it, namely the column, beam, plate, and foundation structures.

Figure 1. Research project location

The method used in this research is quantitative method. This research aims to compare the quantitative results of the structural work construction estimate plan carried out using Autodesk Revit software with the quantitative results on the structural work construction estimate plan conventionally. This research method includes data collection, 3D BIM modeling, cost estimation calculation based on the volume generated using unit cost analysis, and the cost estimation comparison analysis between the use of BIM software and conventional method as shown in Figure 2.

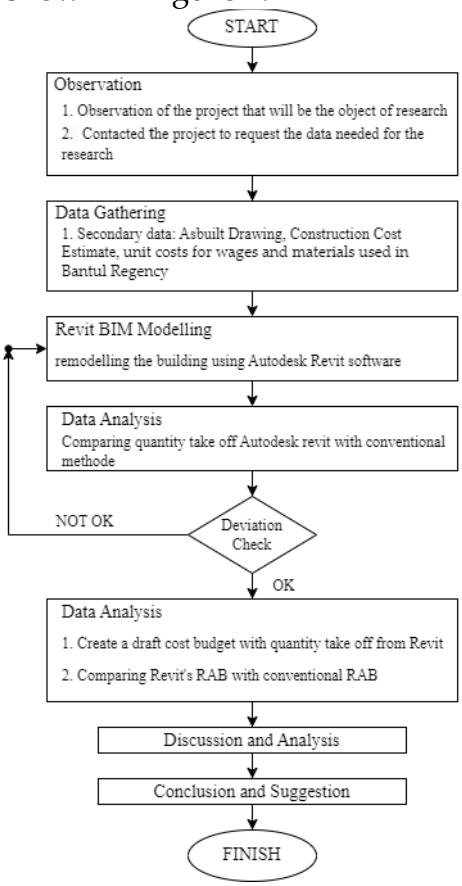

Figure 2. Research flow chart

Result and Discussion

3D Modeling

This research uses Building Information Modeling (BIM) method by using software assistance with BIM systematics named Autodesk Revit. Data processing in this study starts from re-designing the Satpol PP Building Construction project into a 3D model with the required data which is as-build drawing using 2022 version of Autodesk Revit software. Modeling is conducted by drawing foundations, columns, beams, sloofs and floor plates and drawing reinforcement from the ground floor to the 2nd floor according to the plan drawing data. The following in Figure 3. is the results of 3D modeling that has been done in 2022 version of Autodesk Revit software.

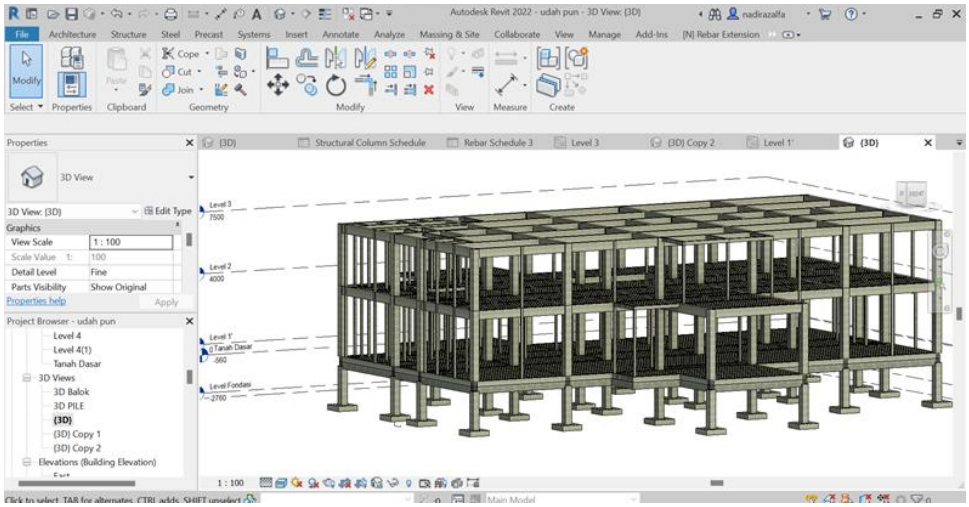

Figure 3. 3D modeling results using the 2022 version of Autodesk Revit software

Quantity take off

The results of 3D modeling that has been done in Revit software is automatically display the Quantity Take Off. QTO can be displayed by selecting the view toolbar then selecting schedule/quantities by adding items and setting the format according to what you want to display. The following in Figure 4. is the result of Quantity Take Off on the column structure that has been carried out in the 2022 version of Autodesk Revit software.

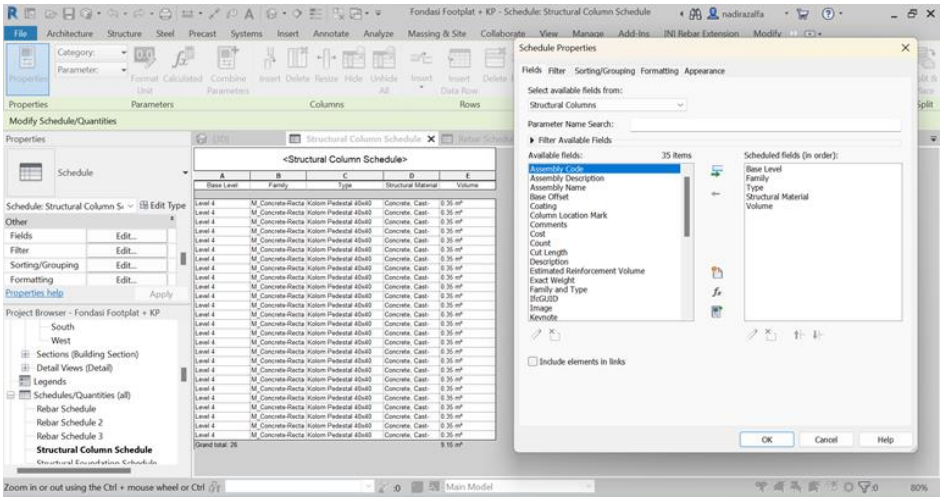

Figure 4. Quantity Take Off on columns structure from 2022 version of Autodesk Revit

Quantity Take Off obtained from Autodesk Revit is then integrated to Microsoft Excel to obtain the recapitulation data listed in Table 1.

Table 1. Recapitulation of quantitiy take off from Autodesk Revit

No	Job Description	Rebar Volume		Concrete Volume	
	1st Floor				
1	Concrete Footplate 125x125 cm, height 30 cm	2120.44	kg	12.19	m3
2	Structural Sloof 20x30 cm	3004.4	kg	13.49	m3
3	Practical Sloof 15x20 cm	285.95	kg	2.27	m3
4	Concrete Main Beam 30x50 cm	5492.79	kg	33.47	m3
5	Concrete Joist 25x40 cm	2402.8	kg	13.8	m3
6	Structural Column 40x40 cm	4984.34	kg	25.79	m3
7	Practical Column 12x12 cm	661.41	kg	3.11	m3
8	Floor Rebate Work 10 cm concrete fc 14,5 MPa			46.83	m3
	2nd Floor				
1	Main Beam 30x50 cm	5229.64	kg	29.07	m3
2	Concrete Joist 25x40 cm	1299.11	kg	7.5	m3
3	Structural Column 40x40 cm	2291.2	kg	13.44	m3
4	Practical Column 12x12 cm	445.84	kg	2.22	m3
5	2nd Floor Plate Work 12 cm	7286.58	kg	48.51	m3

Construction Estimate Plan of BIM Methods

Construction Estimate Plan calculation using the BIM method is carried out by inputting the analysis of the unit cost of concrete and reinforcement work into the Autodesk Revit software, list of unit costs for wages and materials used in the Bantul Satpol PP Building Construction Project refers to the Standardization of Goods and Services Costs of Bantul Regency. Analysis of Unit Cost for Goods of this project also uses the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 1 Year 2022 concerning the Preparation of Construction Cost Estimate in the Field of Public Works and Public Housing to analyze the unit cost of work. Following picture in Figure 5. Is the result of the total cost / cost budget design on beam structure work issued from 2022 version of Autodesk Revit.

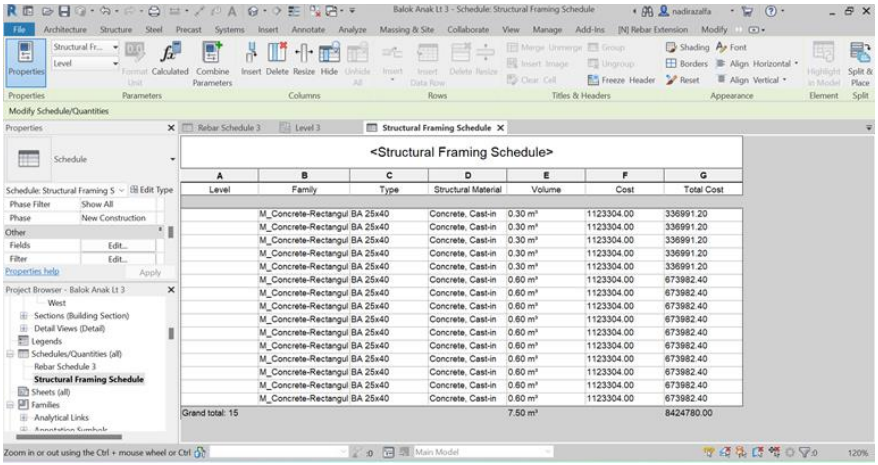

Figure 5. Results of the total cost/budget design of structural beam from 2022 version of Autodesk Revit

The total cost obtained from Autodesk Revit was then integrated into Microsoft Excel to obtain the recapitulation listen in Table 2.

Table 2. Recapitulation of the draft cost budget using Autodesk Revit

No	Job Description	Volume		Unit Cost	Cost
		1st Floor			
1	Concrete Footplate 125x125 cm,				
	Main Rebar Steel D16-150	2120.44	kg	IDR16,389.19	IDR34,752,294.04
	Concrete fc 19,3 MPa	12.19	m3	IDR1,123,304.37	IDR13,693,080.22
2	Structural Sloof 20x30 cm				
	Main Rebar D16	2200.9	Kg	IDR16,389.19	IDR36,070,968.27
	Stirrup 10	803.5	Kg	IDR16,389.19	IDR13,168,714.17
	Concrete fc 19,3 MPa	13.49	m3	IDR1,123,304.37	IDR15,153,375.89
3	Practical Sloof 15x20 cm				
	Main Rebar D10	185.87	Kg	IDR16,389.19	IDR3,046,258.75
	Stirrup 6	100.08	Kg	IDR16,389.19	IDR1,640,230.14
	Concrete fc 14,5 MPa	2.27	m3	IDR1,065,173.80	IDR2,417,944.53
4	Concrete Main Beam 30x50 cm				
	Main Rebar D16	4153.03	kg	IDR16,389.19	IDR68,064,797.75
	Stirrup 10	1339.76	Kg	IDR16,389.19	IDR21,957,581.19
	Concrete fc 19,3 MPa	33.47	m3	IDR1,123,304.37	IDR37,596,997.12
5	Concrete Joist 25x40 cm				
	Main Rebar D16	1791.32	kg	IDR16,389.19	IDR29,358,283.83
	Stirrup 10	645.74	kg	IDR16,389.19	IDR10,583,155.55
	Concrete fc 19,3 MPa	13.8	m3	IDR1,123,304.37	IDR15,501,600.25
6	Structural Column 40x40 cm				
	Main Rebar D16	4118.31	kg	IDR16,389.19	IDR67,495,765.07
	Stirrup 10	866.03	kg	IDR16,389.19	IDR14,193,530.22
	Concrete fc 19,3 MPa	25.79	m3	IDR1,123,304.37	IDR28,970,019.59
7	Practical Column 12x12 cm				
	Main Rebar D10	562.74	kg	IDR16,389.19	IDR9,222,852.78
	Stirrup 6	98.67	kg	IDR16,389.19	IDR1,617,121.38
	Concrete fc 14,5 MPa	3.11	m3	IDR1,065,173.80	IDR3,312,690.53
8	1st Floor 10 cm Concrete Rebate fc 14,5 MPa	46.83	m3	IDR1,065,173.80	IDR49,882,089.20
		2nd Floor			
1	Main Beam 30x50 cm				
	Main Rebar D16	4033.38	kg	IDR16,389.19	IDR66,103,847.55
	Stirrup 10	1196.26	Kg	IDR16,389.19	IDR19,605,732.43
	Concrete fc 19,3 MPa	29.07	m3	IDR1,123,304.37	IDR32,654,457.91
2	Concrete Joist 25x40 cm				
	Main Rebar D16	949.988	kg	IDR16,389.19	IDR15,569,533.83
	Stirrup 10	368.560	kg	IDR16,389.19	IDR6,040,409.70
	Concrete fc 19,3 MPa	7.5	m3	IDR1,123,304.37	IDR8,424,782.74
3	Structural Column 40x40 cm				
	Main Rebar D16	1831.54	kg	IDR16,389.19	IDR30,017,457.05
	Stirrup 10	459.66	kg	IDR16,389.19	IDR7,533,455.08
	Concrete fc 19,3 MPa	13.44	m3	IDR1,123,304.37	IDR15,097,210.68
4	Practical Column 12x12 cm				

No	Job Description	Volume		Unit Cost	Cost
	Main Rebar D10	377.35	kg	IDR16,389.19	IDR6,184,460.85
	Stirrup 6	68.49	kg	IDR16,389.19	IDR1,122,495.62
	Concrete fc 14,5 MPa	2.22	m3	IDR1,065,173.80	IDR2,364,685.84
5	2nd Floor Plate 12cm				
	2 Layer Steel D 10-150	7,286.58	kg	IDR16,389.19	IDR119,421,144.07
	Concrete fc 19,3 MPa	48.51	m3	IDR1,123,304.37	IDR54,491,494.78
	TOTAL				**IDR 862,330,518.59**

Conventional cost estimate plan method

The calculation of the Cost Estimate Plan in a conventional project requires a series of steps. The initial stages include identifying all of the work in the project and grouping the work to form a Work Breakdown Structure (WBS). The next step is to calculate the volume or quantity of each job using manual measurement methods such as area, perimeter, or volume calculations by referring to the project drawings. In this research, the conventional volume calculation uses the backup volume data from the Bantul Satpol PP Building Construction Project which is listed in Table 3.

Table 3. Recapitulation of project structural work volume

No	Job Description	Rebar Volume		Concrete Volume	
	1st Floor				
1	Concrete Footplate 125x125 cm, 30 cm high	1906.11	kg	12.19	m3
2	Structural Sloof 20x30 cm	3444.59	kg	14.36	m3
3	Practical Sloof 15x20 cm	266.05	kg	2.21	m3
4	Concrete Main Beam 30x50 cm	5360.15	kg	31.74	m3
5	Concrete Joist 25x40 cm	2637.55	kg	13.34	m3
6	Structural Column 40x40 cm	5569.63	kg	27.87	m3
7	Practical Column 12x12 cm	733.27	kg	3.02	m3
8	Concrete Floor Rebate 10 cm with Concrete fc 14,5 MPa			46.18	m3
	2nd Floor				
1	Concrete Main Beam 30x50 cm	4926.40	kg	29.22	m3
2	Concrete Joist 25x40 cm	1468.99	kg	5.68	m3
3	Structural Column 40x40 cm	2339.34	kg	13.44	m3
4	Practical Column 12x12 cm	507.76	kg	2.17	m3
5	2nd Floor Concrete Floor Rebate with 12cm thickness	9424.53	kg	53.63	m3

The next stage is to analyze the Unit Cost of Work, in Bantul Satpol PP Building Construction Project using a list of unit Costs for wages and materials referring to the Standardization of Goods and Services Costs of Bantul Regency. The AHSP of this project also uses the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 1 of 2022 about Preparation of Job Cost Estimates. After all the data is collected the next step is to multiply the volume of work with the analysis of the unit cost

of work to make a Construction Estimate Plan. Recapitulation of the construction estimate plan for the Satpol PP Construction Project can be seen in Table 4. Below.

Table 4. Recapitulation of the construction estimate plan with conventional method

No	Job Description	Volume		Unit Cost		Cost
	1st Floor					
1	Concrete Footplate 125x125 cm					
	Main Rebar D16-150	1906.11	kg	IDR	16,389.19	IDR 31,239,598.95
	Concrete fc 19,3 MPa	12.19	m3	IDR	1,123,304.37	IDR 13,693,080.22
2	Structural Sloof 20x30 cm					
	Main Rebar D16	2642.55	Kg	IDR	16,389.19	IDR 43,309,254.03
	Stirrup 10	802.04	Kg	IDR	16,389.19	IDR 13,144,785.95
	Concrete fc 19,3 MPa	14.36	m3	IDR	1,123,304.37	IDR 16,130,650.69
3	Practical Sloof 15x20 cm					
	Main Rebar D10	199.39	Kg	IDR	16,389.19	IDR 3,267,840.59
	Stirrup 6	66.66	Kg	IDR	16,389.19	IDR 1,092,503.41
	Concrete fc 14,5 MPa	2.21	m3	IDR	1,065,173.80	IDR 2,354,034.10
4	Concrete Main Beam 30x50 cm					
	Main Rebar D16	4136.95	kg	IDR	16,389.19	IDR 67,801,259.57
	Stirrup 10	1223.2	Kg	IDR	16,389.19	IDR 20,047,257.21
	Concrete fc 19,3 MPa	31.74	m3	IDR	1,123,304.37	IDR 35,653,680.57
5	Concrete Joist 25x40 cm					
	Main Rebar D16	2045.85	kg	IDR	16,389.19	IDR 33,529,824.36
	Stirrup 10	591.7	kg	IDR	16,389.19	IDR 9,697,483.72
	Concrete fc 19,3 MPa	13.34	m3	IDR	1,123,304.37	IDR 14,984,880.24
6	Structural Column 40x40 cm					
	Main Rebar D16	4589.46	kg	IDR	16,389.19	IDR 75,217,531.94
	Stirrup 10	980.17	kg	IDR	16,389.19	IDR 16,064,192.36
	Concrete fc 19,3 MPa	27.87	m3	IDR	1,123,304.37	IDR 31,306,492.67
7	Practical Column 12x12 cm					
	Main Rebar D10	635.26	kg	IDR	16,389.19	IDR 10,411,396.84
	Stirrup 6	98.01	kg	IDR	16,389.19	IDR 1,606,304.51
	Concrete fc 14,5 MPa	3.02	m3	IDR	1,065,173.80	IDR 3,216,824.89
8	10 cm Floor Rebate, with fc 14,5 MPa Concrete	46.18	m3	IDR	1,065,173.80	IDR 49,189,726.23
	2nd Floor					
1	Main Beam 30x50 cm					
	Main Rebar D16	3801.86	kg	IDR	16,389.19	IDR 62,309,405.89
	Stirrup 10	1124.54	Kg	IDR	16,389.19	IDR 18,430,299.72
	Concrete fc 19,3 MPa	29.22	m3	IDR	1,123,304.37	IDR 32,822,953.57
2	Concrete Joist 25x40 cm					
	Main Rebar D16	1175.52	kg	IDR	16,389.19	IDR 19,265,820.63
	Stirrup 10	293.47	kg	IDR	16,389.19	IDR 4,809,735.59
	Concrete fc 19,3 MPa	5.68	m3	IDR	1,123,304.37	IDR 6,380,368.80
3	Structural Column 40x40 cm					
	Main Rebar D16	1858.08	kg	IDR	16,389.19	IDR 30,452,426.16
	Stirrup 10	481.26	kg	IDR	16,389.19	IDR 7,887,461.58
	Concrete fc 19,3 MPa	13.44	m3	IDR	1,123,304.37	IDR 15,097,210.68
4	Practical Column 12x12 cm					

No	Job Description	Volume		Unit Cost		Cost
	Main Rebar D10	435.16	kg	IDR	16,389.19	IDR 7,131,919.92
	Stirrup 6	72.6	kg	IDR	16,389.19	IDR 1,189,855.19
	Concrete fc 14,5 MPa	2.17	m3	IDR	1,065,173.80	IDR 2,311,427.15
5	2nd Floor Plate Thickness 12cm					
	2 Layer Steel D 10-150	9,424.53	kg	IDR	16,389.19	IDR 154,460,412.83
	Concrete fc 19,3 MPa	53.63	m3	IDR	1,123,304.37	IDR 60,242,813.13
	TOTAL					**IDR 915,750,713.89**

Construction Estimate Plan comparison of conventional and BIM methods

Conventional construction estimate plan obtained a cost of IDR 915,750,713.89 for structural work. Judging from the construction estimate plan that obtained with Building Information Modeling method issued from Autodesk Revit software, there is a cost difference of IDR 53,420,195.31 , where the construction estimate plan of structural work from Revit obtained a value of IDR 862,330,518.59. This shows that the use of 3d BIM concept assisted by Revit software results in a calculation that is 5.83% more cost-effective than the conventional Construction Estimate Plan method. More detailed comparison is contained in Table 5. below.

Table 5. Construction estimate plan comparison between conventional and BIM methods

No	Unit Cost	Revit Cost	Conventional Cost
	1st Floor		
1	Concrete Footplate 125x125 cm		
	Main Rebar D16-150	IDR 34,752,294.04	IDR 31,239,598.95
	Concrete fc 19,3 MPa	IDR 13,693,080.22	IDR 13,693,080.22
2	Structural Sloof 20x30 cm		
	Main Rebar D16	IDR 36,070,968.27	IDR 43,309,254.03
	Stirrup 10	IDR 13,168,714.17	IDR 13,144,785.95
	Concrete fc 19,3 MPa	IDR 15,153,375.89	IDR 16,130,650.69
3	Practical Sloof 15x20 cm		
	Main Rebar D10	IDR 3,046,258.75	IDR 3,267,840.59
	Stirrup 6	IDR 1,640,230.14	IDR 1,092,503.41
	Concrete fc 14,5 MPa	IDR 2,417,944.53	IDR 2,354,034.10
4	Concrete Main Beam 30x50 cm		
	Main Rebar D16	IDR 68,064,797.75	IDR 67,801,259.57
	Stirrup 10	IDR 21,957,581.19	IDR 20,047,257.21
	Concrete fc 19,3 MPa	IDR 37,596,997.12	IDR 35,653,680.57
5	Concrete Joist 25x40 cm		
	Main Rebar D16	IDR 29,358,283.83	IDR 33,529,824.36
	Stirrup 10	IDR 10,583,155.55	IDR 9,697,483.72
	Concrete fc 19,3 MPa	IDR 15,501,600.25	IDR 14,984,880.24
6	Structural Column 40x40 cm		
	Main Rebar D16	IDR 67,495,765.07	IDR 75,217,531.94
	Stirrup 10	IDR 14,193,530.22	IDR 16,064,192.36
	Concrete fc 19,3 MPa	IDR 28,970,019.59	IDR 31,306,492.67
7	Practical Column 12x12 cm		
	Main Rebar D10	IDR 9,222,852.78	IDR 10,411,396.84

No	Unit Cost	Revit Cost	Conventional Cost
	Stirrup 6	IDR 1,617,121.38	IDR 1,606,304.51
	Concrete fc 14,5 MPa	IDR 3,312,690.53	IDR 3,216,824.89
8	10 cm Floor Rebate with Concrete fc 14,5 MPa	IDR 49,882,089.20	IDR 49,189,726.23
	2nd Floor		
1	Main Beam 30x50 cm		
	Main Renar D16	IDR 62,309,405.89	IDR 68,051,850.29
	Stirrup 10	IDR 18,430,299.72	IDR 19,250,906.47
	Concrete fc 19,3 MPa	IDR 32,822,953.57	IDR 32,822,953.57
2	Concrete Joist 25x40 cm		
	Main Rebar D16	IDR 19,265,820.63	IDR 19,265,820.63
	Stirrup 10	IDR 4,809,735.59	IDR 4,809,735.59
	Concrete fc 19,3 MPa	IDR 6,380,368.80	IDR 6,380,368.80
3	Structural Concrete 40x40 cm		
	Main Rebar D16	IDR 30,452,426.16	IDR 30,099,075.22
	Stirrup 10	IDR 7,887,461.58	IDR 7,350,551.72
	Concrete fc 19,3 MPa	IDR 15,097,210.68	IDR 15,097,210.68
4	Practical Column 12x12 cm		
	Main Rebar D10	IDR 7,131,919.92	IDR 7,131,919.92
	Stirrup 6	IDR 1,189,855.19	IDR 1,063,658.43
	Concrete fc 14,5 MPa	IDR 2,311,427.15	IDR 2,311,427.15
5	2nd Floor Plate with 12cm thickness		
	2 Layer Steel D 10-150	IDR 154,460,412.83	IDR 143,946,091.88
	Concrete fc 19,3 MPa	IDR 60,242,813.13	IDR 60,242,813.13
	TOTAL	**IDR 862,330,518.59**	**IDR 915,750,713.89**
	DIFFERENCE	**IDR 53,420,195.31**	

Comparison of the volume of conventional method reinforcement is greater than the volume of BIM method reinforcement, this is due to the absence of connection details which affect the number of differences in quantity taken off between conventional and Revit methods, so that the reinforcement connection applied in the Revit method is based on the assumption of the applicable SNI standard. Similarly, the comparison of casting volume in the conventional method is greater than that in Revit. This difference factor occurs because in the Bantul Satpol PP Construction project relies on 2D drawings with estimated material quantity control. On the other hand, using Autodesk Revit, 2D working drawings can be converted into 3D models that allow more accurate calculation of material volume so as to reduce material waste, and support more accurate cost estimation calculations in 5D. Detailed comparison of the difference between conventional concrete volume and Revit volume is shown in Table 6. below.

Table 6. Volume comparison of conventional and BIM methods

Job Description	Revit Volume	Conventional Volume	Difference	Percentage
Reinforcement	35,558.20	38,584.37	3,026.17	8.51%
Concrete	251.69	255.05	3.36	1.3%

Conclusion

Within the research conducted to evaluate the application of 3D Building Information Modeling (BIM) in supporting structural work cost estimation, several conclusions can be drawn as follows, the application of the concept of Building Information Modeling (BIM) 3D on structural work in Bantul Yogyakarta Satpol PP Building Construction project obtained a casting volume of 251,69 m3 and reinforcement volume of 35.558,20 kg. The construction estimate plan for structural work on the Bantul Yogyakarta Satpol PP Building Construction Project by applying Building Information Modeling (BIM) is IDR 862,330,518.59. The difference between calculations of the cost of structural work using the 5D Building Information Modeling (BIM) method in the Bantul Yohyakarta Satpol PP Building Construction Project is IDR 53,420,195.31. This means that using the 5D Building Information Modeling (BIM) method with the help ot Autodesk Revit software results in a lower cost estimate, which is around 5,83% compared to the conventional cost calculation listed in the project document.

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