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Comparative Analysis of Material Take-Off Structure (North Building) B.Ut.2 UT.75 Based on BIM (Building Information Modeling) between Autodesk Revit and Manual Quantity Calculation in LMS-02 Range Irrigation Project

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ABSTRACT
The material estimation process in construction projects is a crucial step in planning and cost control. However, conventional methods such as manual calculations often take a long time and have a high potential for error. With the development of Building Information Modeling (BIM) technology, software such as Autodesk Revit offers a more efficient solution in performing Material Take-Off (MTO). This research aims to analyze the comparison of the results of the MTO calculation of the North Building structure (B.Ut.2) UT.75 in the LMS-02 Range Irrigation Project using Autodesk Revit and manual calculation methods, to find out the extent of the difference between the two methods in terms of accuracy, time efficiency, and effectiveness of their application in construction projects. The research method used is a quantitative study with a comparative approach to analyze that MTO calculations using Autodesk Revit are faster than manual methods, with a high level of accuracy in material quantification. In addition, the application of BIM in the MTO process can minimize the potential for human error and improve efficiency in project management.

Keywords: Autodesk Revit, Building Information Modeling (BIM), Material Take-Off (MTO), Efficiency.

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INTRODUCTION

In construction projects, Material Take-Off (MTO) is a critical process that impacts the efficiency of time, cost, and resources. Accurate MTO ensures efficient material management and minimizes waste. For this reason, traditional methods like manual calculations are being upgraded with modern technologies such as Building Information Modeling (BIM), implemented using software like Autodesk Revit. BIM is a technology that enables the integration of project data from various disciplines into a single digital model. The use of BIM, such as Autodesk Revit, allows for more efficient and accurate project planning, design, and management. BIM facilitates better team collaboration, centralized data management, and clearer project visualization, all of which contribute to improved efficiency. Additionally, BIM provides accurate 3D models of projects, assisting in material volume calculations, model conflict detection (clash detection/clash analysis), and better construction planning. Thus, efficiency and accuracy are two main pillars that support the success of construction projects. Integrating these aspects through technologies like BIM can offer significant benefits in terms of cost savings, quality improvement, and client satisfaction. This study aims to analyze how the use of

Autodesk Revit within BIM enhances the efficiency and accuracy of Material Take-Off compared to manual calculation methods.

BIM (Building Information Modeling) is an innovative approach that integrates technology and workflows to enhance efficiency and effectiveness in planning, design, construction, and building management. Some core concepts of BIM are Integrated 3D Model, Coordination and Collaboration, Information Management, Simulation and Analysis, Automation and Efficiency, Visualization and Presentation, and Facility Management.

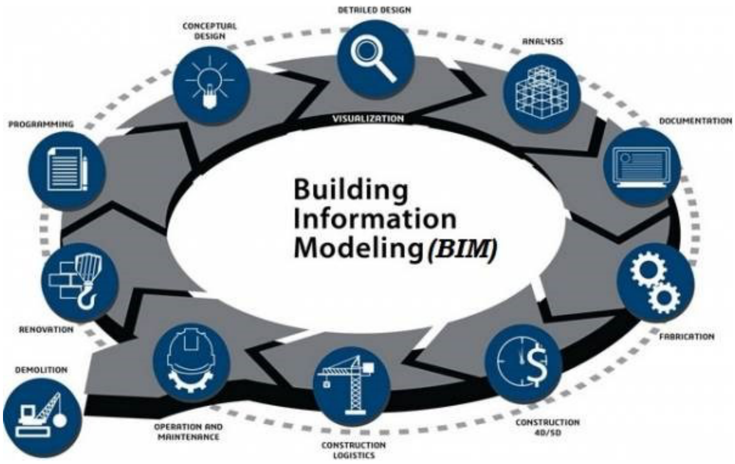


Figure 1. Implementation Building Information Modeling

This research focuses on comparing the efficiency and accuracy of Material Take-Off (MTO) calculations between Autodesk Revit software and manual methods for specific concrete items (B1, D1, and A1) within the North Building structure B.Ut.2 UT.75 in the LMS-02 Range Irrigation Project, segment A to F, excluding cost and overall project management aspects. The study aims to analyze the accuracy and efficiency of both methods, identify their advantages and disadvantages, and compare the MTO results generated by Autodesk Revit with those from manual calculations.

METHOD

The research design utilizes design drawings aimed at providing clear guidance for conducting effective and efficient research on the B.Ut.2 structure, particularly regarding MTO analysis and the use of BIM software for design optimization. The layout of B.Ut.2 includes civil layout plans, cross sections, long sections, and detailed drawings. This structure is an intake building designed to regulate and distribute water discharge from the primary canal to secondary and tertiary canals. A 3D model of the B.Ut.2 structure can be developed using Building Information Modeling (BIM) software, such as Autodesk Revit.

The research is conducted at the Rentang Irrigation Modernization Project (RIMP) LMS-02, located in Sukaperna Village, Tukdana Sub-district, Indramayu Regency, West Java Province, specifically at B.Ut.2 UT.75. The location map of the study area is shown as follows:

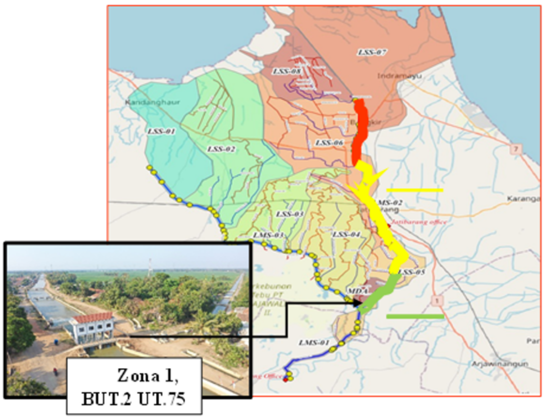


Figure 2. Location of B.Ut.2

The research data collection method is an important process in construction planning that aims to obtain an accurate estimate of the material quantity before starting the research which is used for cost calculation, material management of the work. Data collection for MTO can be done through several methods. The primary data collection method is information obtained through direct observation in the field. This data will be processed for further analysis so that when the 3D model can bring up the Material Take-Off (MTO) volume, it can be compared with manual calculations. Secondary data collection is carried out by viewing and studying the design drawing plans that have been approved by the supervision consultant and owner. The data is needed to find out the 2D design which will later be adopted into 3D images. The image includes a plan drawing, a cut view, so that when it becomes a 3D model, the details of the material volume will appear.

The series of research activities are organized to display a systematic series of research and inform about the research process carried out from the initial stage to provide technical recommendations.

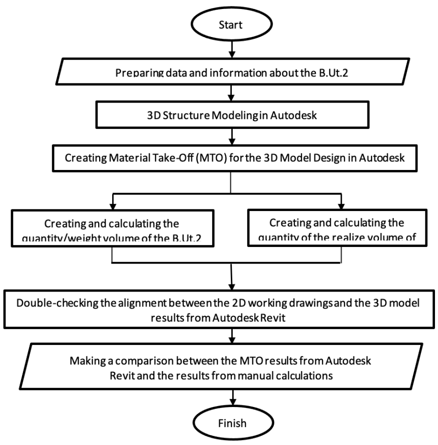
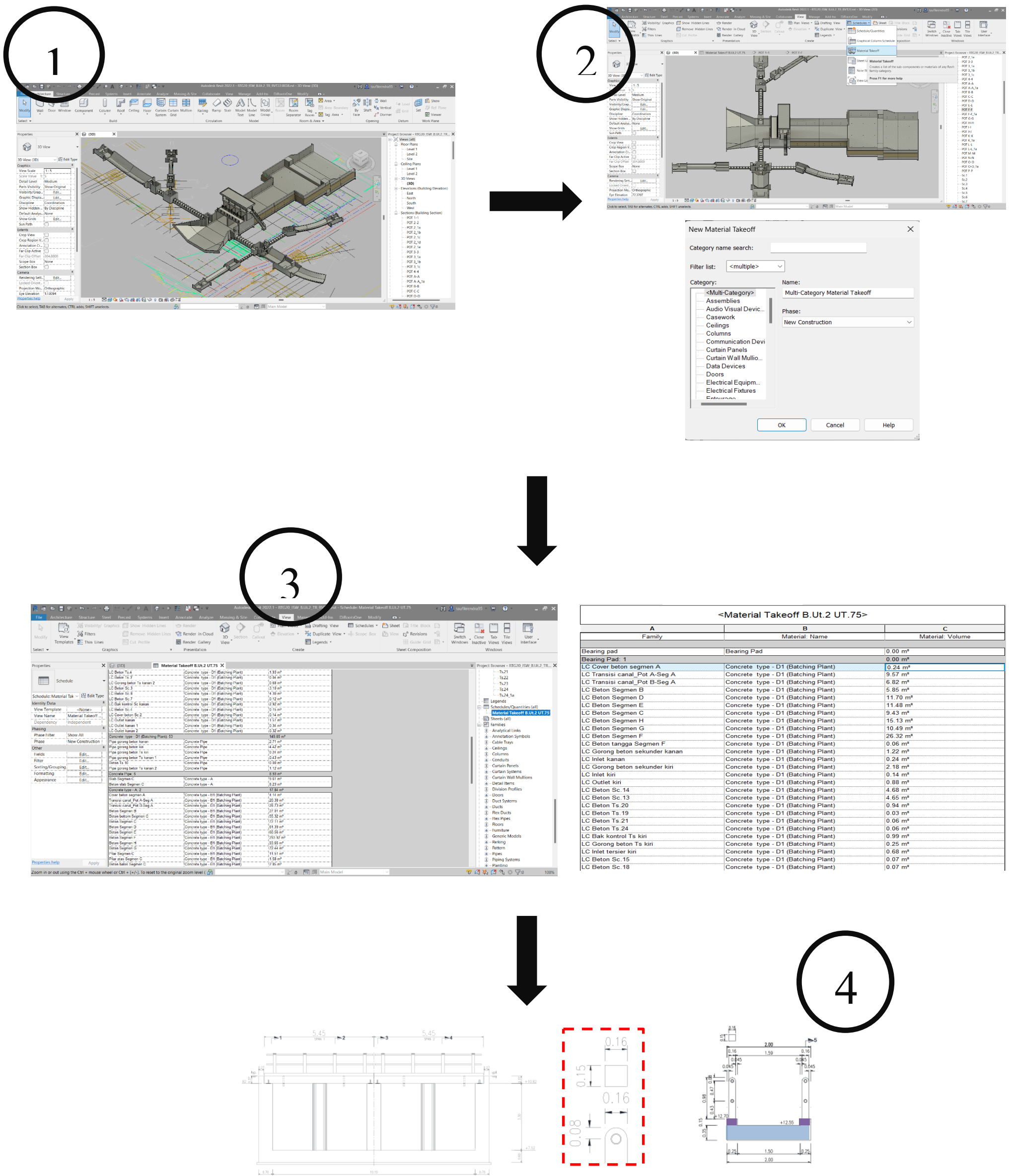


Figure 3. Revit Material Take-Off Research Flow Chart vs Manual Calculation

RESULTS AND DISCUSSION

The results and discussion of the manual calculation will be explained in Figure 3, and the workflow explanation will be discussed in Table 1 below.



Volume Concrete Type - A (Foot Bridge Span 1 L = 5,45 m)

Dimensi 1 Lantai

Panjang	=	5.45	m
Lebar	=	2.00	m
Tinggi	=	0.35	m
Jumlah	=	2	

Volume = Panjang x Lebar x Tinggi x Jumlah
= 5.45 x 2.00 x 0.35 x 2 = 7.630 m³

Dimensi 2 Dudukan Railling

Panjang	=	5.45	m
Lebar	=	0.16	m
Tinggi	=	0.15	m
Jumlah	=	4	

Volume = Panjang x Lebar x Tinggi x Jumlah
= 5.45 x 0.25 x 0.15 x 4 = 0.818 m³

Figure 4. Flow Analysis of Revit Material Take-Off Comparison vs Manual Calculation

Table 1. Explanation of the Flowchart

No	Explanation
1	Modeling the 3D design of the B.Ut.2 building structure model using Autodesk Revit software
2	Set the material items that will be made Take-Off material in Autodesk Revit
3	Material Take-Off table view from Autodesk Revit
4	Perform manual quantity calculations then compare with MTO Revit

Manual quantitiy calculation analysis refers to the DWG file approval structure design, which is a mutually agreed structural drawing design that will later be applied as a reference for working drawings in the field. Based on the manual quantitiy calculation above, the volume data recap is obtained as follows:

No.		Item Name	Segment	Volume QuantityManual	Unit
1		**Concrete type - A1 (Batching Plant)**			
	1	Foot Bridge	Segment C	7.630	m³
	2	Railing Stand	Segment C	0.818	m³
	3	Railing Beton	Segment C	0.370	m³
	4	Floor Door Regulator	Segment C	9.384	m³
2		**Concrete type - B1 (Batching Plant)**			
	1	Cover Concrete	Segment A	3.989	m³
	2	Transitional Concrete	Segment A	50.543	m³
	3	Bottom & Wall Pot A-A	Segment B	4.975	m³
	4	Intake Kiri	Segment B	6.372	m³
	5	Intake Kanan	Segment B	6.430	m³
	6	Lower Pillars	Segment C	68.572	m³
	7	Bottom Pilar Bawah	Segment C	53.179	m³
	8	Upper Pillar	Segment C	9.724	m³
	9	Pillar Cross-section	Segment C	1.760	m³
	10	Column	Segment C	2.094	m³
	11	Beam	Segment C	1.296	m³
	12	Deck Plates / Roof Plates	Segment C	9.082	m³
	13	List Plank Atap	Segment C	2.124	m³
	14	Concrete Stair Supports	Segment C	0.118	m³
	15	Ladder	Segment C	2.794	m³
	16	Balok Pear Foot Bridge	Segment C	0.617	m³
	17	Bottom & Wall	Segment D	61.450	m³
	18	Bottom & Wall	Segment E	63.294	m³
	19	Bottom & Wall	Segment F	283.700	m³
3		**Concrete type - D1 (B atching Plant)**			
	1	LC Cover Concrete	Segment A	0.419	m³

2	LC Concrete Transition	Segment A	14.661	m^3
3	LC Bottom	Segment B	5.850	m^3
4	LC Intake Left	Segment B	0.270	m^3
5	LC Intake Right	Segment B	0.300	m^3
6	LC Bottom Pilar	Segment C	9.269	m^3
7	LC Bottom	Segment D	11.700	m^3
8	LC Bottom	Segment E	12.051	m^3
9	LC Bottom	Segment F	26.166	m^3

The results of the manual calculation will then be compared with the MTO results from the 3D Autodesk Revit that has been modeled. The deviation between the results of the Autodesk Revit BIM-based Material Take-Off (MTO) calculation and the manual calculation on the 3D structural model B.Ut.2 is an approach to identify quantitative differences between the two methods. For the percentage of deviation of the comparison, there is actually no limit, but by considering the error value by taking the waste material coefficient, the management of the service provider decided to be equal to the comparison between manual calculation and MTO Revit is ± 3%. In addition to comparing the volume results, this is also used to evaluate the level of accuracy of the 3D BIM model, as well as to find the efficiency of the calculation method.

Deviation is calculated for each type of material item using the formula:

$$\text{Deviation} = \frac{\text{BIM Result} - \text{Manual Result}}{\text{Manual Result}} \times 100\%$$

- Positive Deviation: Indicates that the BIM estimate is greater than the manual calculation.
- Negative Deviation: Indicates that the BIM estimate is smaller than the manual calculation.

With the results of this deviation, it will be used as an analysis of the level of detail of the 3D BIM model in the depiction of the 3D model (Level of Detail / LOD) which can affect MTO. The following is a comparison table of the results of the 3D MTO BIM Autodesk Revit model with the results of manual comparison. The items analyzed for comparison are taken from several samples such as Concrete type-A1 (K-225), Concrete type-B1 (K-175) and Concrete type-D1 (K-100):

COMPARISON OF MTO BIM VS QUANTITY MANUAL

No	Item Name	Unit	Segment	Volume		Deviation	%
				BIM	Quantity		
a	b	c	d	and	f	g=(e-f)/f	h=g/100%
1	**Concrete type - A1 (Batching Plant)**						

1	Foot Bridge	m^3	Segment C	7.640	7.630	0.001	0%
2	Railing Stand	m^3	Segment C	0.820	0.818	0.003	0%
3	Railing Beton	m^3	Segment C	0.370	0.370	0.001	0%
4	Floor Door Regulator	m^3	Segment C	9.500	9.384	0.012	1%
2	**Concrete type - B1 (Batching Plant)**						
1	Cover Concrete	m^3	Segment A	4.000	3.994	0.001	0%
2	Transitional Concrete	m^3	Segment A	50.830	50.543	0.006	1%
3	Bottom & Wall Pot A-A	m^3	Segment B	27.010	26.975	0.001	0%
4	Intake Kiri	m^3	Segment B	6.750	6.739	0.002	0%
5	Intake Kanan	m^3	Segment B	6.950	6.797	0.022	2%
6	Pilar Bawah + Balok Pear Foot Bridge	m^3	Segment C	70.230	68.573	0.024	2%
7	Bottom Pilar Bawah	m^3	Segment C	55.310	55.269	0.001	0%
8	Upper Pillar + Pillar Cross Sectional	m^3	Segment C	11.510	11.484	0.002	0%
9	Column + Beam	m^3	Segment C	3.820	3.808	0.003	0%
10	Deck Plate/Roof Plate + List Roof Shelf	m^3	Segment C	11.210	11.206	0.000	0%
11	Concrete Stair Supports	m^3	Segment C	0.120	0.118	0.016	2%
12	Ladder	m^3	Segment C	2.840	2.793	0.017	2%
13	Bottom & Wall	m^3	Segment D	61.390	61.450	-0.001	0%
14	Bottom & Wall	m^3	Segment E	63.230	63.294	-0.001	0%
15	Bottom & Wall	m^3	Segment F	290.780	283.701	0.025	2%
3	**Concrete type - D1 (Batching Plant)**						
1	LC Cover Concrete	m^3	Segment A	0.420	0.419	0.002	0%
2	LC Concrete Transition 1	m^3	Segment A	14.760	14.634	0.009	1%
3	LC Bottom	m^3	Segment B	5.850	5.850	0.000	0%
4	LC Intake Left	m^3	Segment B	0.270	0.270	0.000	0%
5	LC Intake Right	m^3	Segment B	0.300	0.300	0.000	0%
6	LC Bottom Pilar	m^3	Segment C	9.290	9.269	0.002	0%
7	LC Bottom	m^3	Segment D	11.700	11.700	0.000	0%
8	LC Bottom	m^3	Segment E	12.050	12.051	0.000	0%
9	LC Bottom	m^3	Segment F	26.290	26.166	0.005	0%

Data collection in the field aims to ensure the volume and realization of work in accordance with planning specifications and become the basis for evaluation of project progress reports. Researchers tried to re-measure the construction of the finished B.Ut.2 building in the form of a structure in the field to take data on the volume of realization.

After observation in the field, the data obtained from the volume realization of the B.Ut.2 structure is as follows:

No.	Item Name	Segment	Volume QuantityManual	Unit
1	**Concrete type - A1 (Batching Plant)**			
1	Foot Bridge	Segment C	7.630	m^3
2	Railing Stand	Segment C	0.818	m^3
3	Railing Beton	Segment C	0.370	m^3
4	Floor Door Regulator	Segment C	9.384	m^3
2	**Concrete type - B1 (Batching Plant)**			
1	Cover Concrete	Segment A	3.994	m^3
2	Transitional Concrete	Segment A	50.543	m^3
3	Bottom & Wall Pot A-A	Segment B	4.975	m^3
4	Intake Kiri	Segment B	6.739	m^3
5	Intake Kanan	Segment B	6.797	m^3
6	Lower Pillars	Segment C	68.573	m^3
7	Bottom Pilar Bawah	Segment C	55.269	m^3
8	Upper Pillar	Segment C	9.72	m^3
9	Pillar Cross-section	Segment C	1.760	m^3
10	Column	Segment C	2.513	m^3
11	Beam	Segment C	1.296	m^3
12	Deck Plates / Roof Plates	Segment C	9.082	m^3
13	List Plank Atap	Segment C	2.124	m^3
14	Concrete Stair Supports	Segment C	0.118	m^3
15	Ladder	Segment C	2.79	m^3
16	Bottom & Wall	Segment D	61.450	m^3
17	Bottom & Wall	Segment E	63.294	m^3
18	Bottom & Wall	Segment F	283.701	m^3
3	**Concrete type - D1 (Batching Plant)**			
1	LC Cover Concrete	Segment A	0.419	m^3
2	LC Concrete Transition	Segment A	14.634	m^3
3	LC Bottom	Segment B	5.850	m^3
4	LC Intake Left	Segment B	0.270	m^3
5	LC Intake Right	Segment B	0.300	m^3
6	LC Bottom Pilar	Segment C	9.269	m^3
7	LC Bottom	Segment D	11.700	m^3
8	LC Bottom	Segment E	12.051	m^3
9	LC Bottom	Segment F	26.166	m^3

The volume results are obtained from measurements in the field which are then checked for dimensions using the reference work drawings that have been approved. Then the researchers recapitulated the results of measuring the dimensions of the B.Ut.2 building structure into the cheklist form and calculated the total volume adjusting to the items to be studied. After everything is recapitulated and adjusted, then the next step is to compare the results of the structural measurement volume realization in the field with MTO Revit. The MTO Revit comparison recap table and the results of the realization volume measurements are as follows:

COMPARISON OF MTO BIM VS VOLUME REALIZATION

No	Item Name	Unit	Segment	Volume		Deviation	%
				BIM	Quantity		
a	b	c	d	and	f	g=(e-f)/f	h=g/100%
1	**Concrete type - A1 (Batching Plant)**						
1	Foot Bridge	m³	Segment C	7.640	7.630	0.001	0%
2	Railing Stand	m³	Segment C	0.820	0.818	0.003	0%
3	Railing Beton	m³	Segment C	0.370	0.370	0.001	0%
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2	**Concrete type - B1 (Batching Plant)**						
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2	Transitional Concrete	m³	Segment A	50.830	50.543	0.006	1%
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9	Column + Beam	m³	Segment C	3.820	3.808	0.003	0%
10	Deck Plate/Roof Plate + List Roof Shelf	m³	Segment C	11.210	11.206	0.000	0%
11	Concrete Stair Supports	m³	Segment C	0.120	0.118	0.016	2%
12	Ladder	m³	Segment C	2.840	2.795	0.016	2%
13	Bottom & Wall	m³	Segment D	61.390	61.450	-0.001	0%
14	Bottom & Wall	m³	Segment E	63.230	63.294	-0.001	0%
15	Bottom & Wall	m³	Segment F	290.780	283.701	0.025	2%
3	**Concrete type - D1 (Batching Plant)**						
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5	LC Intake Right	m^3	Segment B	0.300	0.300	0.000	0%
6	LC Bottom Pilar	m^3	Segment C	9.290	9.269	0.002	0%
7	LC Bottom	m^3	Segment D	11.700	11.700	0.000	0%
8	LC Bottom	m^3	Segment E	12.050	12.051	0.000	0%
9	LC Bottom	m^3	Segment F	26.290	26.166	0.005	0%

The results of the analysis show that manual calculations plus checking the dimensions of the realized structure are appropriate, and the deviation results from the comparison of MTO calculations and manual calculations are not more than ± 2%, which means that Autodesk Revit MTO produces accurate and detailed volumes or data due to direct processing of the modeled 3D modeling. BIM allows the preparation of Material Take Off (MTO) digitally to calculate precise material requirements based on project design. However, it is important to compare these BIM MTO results with the actual volumes in the field to ensure conformity between plan and implementation.

CONCLUSION

The research concludes that Autodesk Revit MTO provides accurate and detailed volumes for the North Building structure (B.Ut.2) UT.75 with deviations within ±2% compared to manual calculations, owing to its direct processing of 3D models and minimizing interpretation errors. Autodesk Revit significantly enhances efficiency by directly generating volumes from the 3D model, reducing the time and resources required compared to manual methods, which rely on drawing interpretation and multiple quantity surveyors. Future research could explore the integration of cost analysis and project management aspects to provide a more comprehensive understanding of the benefits of BIM in construction projects.

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