Comparison of Cut and Fill Volume Calculation Using Building Information Modeling (BIM) and Conventional Methods (Cut and Fill Project of KIT Batang, Block A Lots 9, 10, 11, 12, and 12A)

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Abstract. Land preparation is a crucial initial stage in construction work to adjust the site's topography to the planned elevation. One of the main activities in this phase is earthwork, specifically the cut and fill process. This study compares the conventional method and the Building Information Modeling (BIM) method in calculating earthwork volumes for the Cut & Fill Project at KIT Batang, Block A Lots 9, 10, 11, 12, and 12A. The conventional method uses AutoCAD, Civil 3D, and Microsoft Excel with the Average End Area method, while the BIM method applies an integrated 3D digital model in Civil 3D through the Compute Materials and Volumes Dashboard commands. The results show that the conventional method produced excavation (cut) and embankment (fill) volumes of 5,715.65 m^3 and 111,196.22 m^3, respectively. Meanwhile, the BIM method generated 5,894.19 m^3 (cut) and 112,093.61 m^3 (fill) using Compute Materials, and 5,665.10 m^3 (cut) and 112,038.57 m^3 (fill) using Volumes Dashboard. The deviation of BIM results compared to the conventional method was less than 5%, with +3.12% and +0.81% for Compute Materials, and –0.88% and +0.76% for Volumes Dashboard. These small deviations indicate that the BIM method provides higher accuracy and efficiency, as it automatically calculates volumes based on an integrated digital surface model, reducing potential human error.

Keywords: Cut and Fill, Earthwork, Conventional Method, Building Information Modeling (BIM), Civil 3D

1. Introduction

Earthwork is a crucial initial stage in construction, particularly in the cut and fill process, which functions to adjust the natural topography to the planned elevation. The accuracy of volume calculations greatly influences cost estimation, project duration, and resource efficiency[1]. Conventionally, the calculation of cut and fill volumes is performed manually using the cross-section method with the aid of software such as AutoCAD, Civil 3D, and Microsoft Excel[2].

The advancement of digital technology has introduced the Building Information Modeling (BIM) approach, which enables automatic volume computation through three-dimensional modeling with a higher level of accuracy. In the Cut and Fill Project of the Kawasan Industri Terpadu (KIT) Batang, calculation accuracy is essential to ensure the availability of construction-ready land that is both cost-effective and time-efficient. This study compares the conventional method and the BIM method in calculating cut and fill volumes to evaluate their levels of accuracy, efficiency, and potential application in future infrastructure projects.

2. Methods

2.1. Research Methodology

The reserch design is as follows:

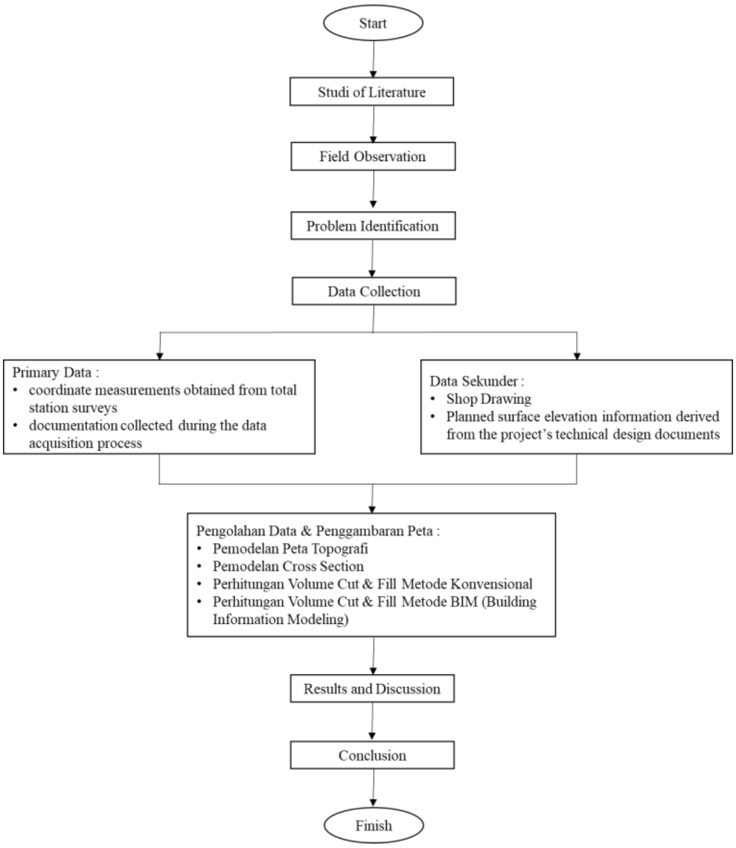

Figure 1. Research Methodology

2.2. Data Collection Technique

The following are the techniques used by the author to obtain the data needed in the research:

Studi of Literature: The literature study was conducted to obtain a theoretical foundation relevant to earthwork volume calculations using both conventional methods and Building Information Modeling (BIM). The literature sources include books, journals, design standards, and previous research, which serve as the basis for developing the methodology, data analysis, and discussion of research findings.

Field Observation: Field observations were carried out to provide a real picture of the existing conditions in the KIT Batang cut and fill project. This activity aimed to identify field conditions, existing phenomena, and potential problems, allowing the researcher to determine the appropriate focus and direction of the study.

Problem Identification: The results of the field observations were analyzed to identify the main issues related to the efficiency and accuracy of earthwork volume calculations. The most relevant problems were then used as the basis for formulating the research focus.

Data Collection: The data used in this study consist of two types : primary data and secondary data. The primary data include coordinate measurements obtained from total station surveys as well as documentation collected during the data acquisition process. The secondary data comprise shop drawings and planned surface elevation information derived from the project's technical design documents. Both types of data were utilized for topographic modeling and for comparing the existing ground conditions with the planned design surfaces.

Data Processing: Both primary and secondary data were processed using two different methods. The conventional method involved the use of AutoCAD, Civil 3D, and Microsoft Excel, applying the Average End Area Method approach to calculate cut and fill volumes. In contrast, the Building Information Modeling (BIM) method utilized Civil 3D in an integrated workflow to model and calculate volumes automatically through the Compute Materials and Volumes Dashboard commands.

Results and Discussion: The data processing results are presented in the form of a comparison between cut and fill volumes obtained from the conventional and BIM methods. The analysis was conducted to evaluate time efficiency (cycle time) and the accuracy of the calculation results.

Conclusion: The conclusions were drawn based on the analysis of volume comparison and time efficiency between the conventional and BIM methods, in accordance with the research objectives.

2.3. Data Analysis Technique

The analysis was conducted computationally through the following steps:

Data Collection: Primary data were obtained through direct measurements using a total station, while secondary data, including shop drawings and planned elevation data, were collected from project documentation. The measurement results were then used to create an existing topographic model.

Conventional Data Processing :

The conventional data processing was carried out through several steps:

a. Inputting survey data into Microsoft Excel and Civil 3D to generate the contour surface.
b. Creating cross-sections based on the contour surface.
c. Determining the elevation of each section through data interpolation.
d. Conducting cut and fill analysis by calculating the area of each cross-section.
e. Calculating the total volume using the Average End Area Method, as expressed in the following formula:

$$V = \left(\frac{A_1 + A_2}{2}\right) \times L$$

Explanation,
V = Earthwork volume (m³)
A_1 = Area of the first cross-section (m²)
A_1 = Area of the second cross-section (m²)
L = Distance between cross-sections (m)

BIM Data Processing: Measurement data were processed directly in Civil 3D through a single workflow cycle, including data import, creation of existing and design surfaces, generation of cross-sections, and automatic volume calculation using the Compute Materials and Volumes Dashboard commands.

2.4. Previous Reseach
The analysis was conducted computationally through the following steps:

Table 1. Research on weather/rain prediction

Reference	Result	Method
[3]	The BIM method produced more accurate volume calculations and greater time efficiency compared to the conventional method.	Comparison of Conventional and BIM using Civil 3D
[4]	BIM minimized data input errors and automatically generated volume results integrated with 3D models.	Implementation of BIM in Digital Modeling
[5]	The conventional method provided satisfactory results but required more time and was prone to manual errors; BIM application is recommended for time efficiency.	Planning of Cut and Fill Work using Conventional vs BIM
[6]	The use of BIM reduced material waste and improved estimation efficiency compared to the conventional method.	Application of BIM for Quantity Take-Off Estimation
[7]	BIM implementation improved calculation accuracy by approximately ±3% and reduced processing time by about 20% compared to the conventional method.	Evaluating the impact of BIM implementation on the accuracy and processing time of earthwork volume calculations in infrastructure projects.

3. Results and Discussion

This study generally discusses the comparison of earthwork volume calculation methods between the conventional method and the Building Information Modeling (BIM) method in the Cut and Fill Project of the Batang Integrated Industrial Estate (KIT Batang), specifically at Block A Lots 9, 10, 11, 12, and 12A, located in Ketanggan Village, Gringsing District, Batang Regency, Central Java. The research site has two different design elevations: +10.30 m for Lots 9, 10, and 11, and +5.00 m for Lots 12 and 12A.

3.1. Conventional Data Processing

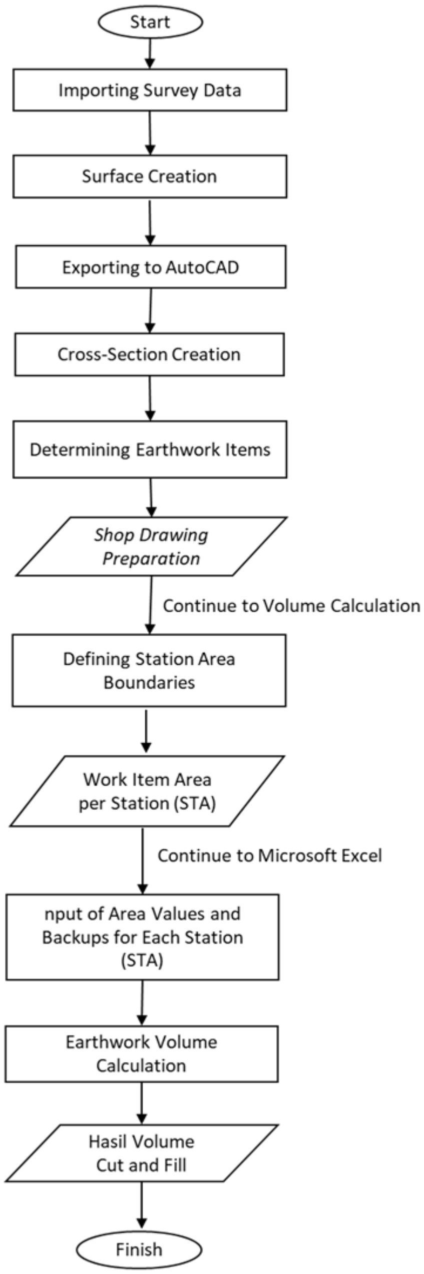

Figure 2 Flowchart of Conventional Data Processing Method

The conventional method employs three separate software programs: Civil 3D, AutoCAD, and Microsoft Excel. The processing stages include:

Importing Survey Data: Field measurement coordinate data are imported into Civil 3D as the basis for creating the existing surface model.

Surface Creation: The point data are processed into contour lines to form a 3D existing surface, which serves as a reference for cut and fill volume calculations.

Exporting to AutoCAD: The surface model from Civil 3D is exported to AutoCAD for visualization in 2D format.

Cross-Section Creation: The lot's centerline is used as the reference for the longitudinal profile, while cross-sections are created at 20-meter intervals for each station (STA). These cross-sections serve as the basis for calculating excavation and embankment volumes.

Shop Drawing Preparation: Working drawings are prepared based on the created cross-sections, showing the boundaries of the cut and fill areas to ensure alignment between the design plan and field conditions.

Defining Station Area Boundaries: Boundaries are defined for each STA to allow segmented volume calculations, improving the accuracy of the results.

Earthwork Volume Calculation: The volume is calculated using the Average End Area Method.

The results of the excavation (cut) and embankment (fill) earthwork volume calculations for the Cut and Fill Project of KIT Batang, Block A Lots 9, 10, 11, 12, and 12A, are as follows:

Table 1 Cut Volume Calculation

NO	STA	Cross-Sectional Cut Area (m2)	Average Area (m2)	Distance (m)	Volume (m3)	Cumulative Volume (m3)
1	0+000.000	40,91				
2	0+020.000	29,30	35,10	20,00	702,09	702,09
3	0+040.000	26,51	27,90	20,00	558,04	1.260,13
4	0+060.000	16,67	21,59	20,00	431,74	1.691,87
5	0+080.000	25,74	21,20	20,00	424,05	2.115,92
6	0+100.000	40,33	33,03	20,00	660,66	2.776,58
7	0+120.000	-	20,16	20,00	403,27	3.179,85
8	0+140.000	-	-	20,00	-	3.179,85
9	0+160.000	-	-	20,00	-	3.179,85
10	0+180.000	17,58	8,79	20,00	175,76	3.355,61
11	0+200.000	49,70	33,64	20,00	672,80	4.028,41
12	0+220.000	59,51	54,61	20,00	1.092,14	5.120,55
13	0+240.000	-	29,76	20,00	595,10	5.715,65
14	0+260.000	-	-	20,00	-	5.715,65
15	0+280.000	-	-	20,00	-	5.715,65
					TOTAL	5.715,65

Table 2 Fill Volume Calculation

NO	STA	Cross-Sectional Cut Area (m2)	Average Area (m2)	Distance (m)	Volume (m3)	Cumulative Volume (m3)
1	0+000.000	179,81				
2	0+020.000	190,31	185,06	20,00	3.701,19	3.701,19
3	0+040.000	192,45	191,38	20,00	3.827,50	7.528,69
4	0+060.000	187,47	189,96	20,00	3.799,16	11.327,85
5	0+080.000	184,50	185,99	20,00	3.719,72	15.047,57
6	0+100.000	171,57	178,04	20,00	3.560,73	18.608,30
7	0+120.000	705,21	438,39	20,00	8.767,79	27.376,09
8	0+140.000	609,65	657,43	20,00	13.148,52	40.524,61
9	0+160.000	457,36	533,50	20,00	10.670,05	51.194,66
10	0+180.000	333,70	395,53	20,00	7.910,61	59.105,27
11	0+200.000	338,03	335,87	20,00	6.717,31	65.822,58
12	0+220.000	353,35	345,69	20,00	6.913,77	72.736,35
13	0+240.000	512,25	432,80	20,00	8.655,99	81.392,34
14	0+260.000	789,66	650,96	20,00	13.019,16	94.411,50
15	0+280.000	888,81	839,24	20,00	16.784,72	111.196,22
					TOTAL	111.196,22

Based on the results of data processing using the conventional method, the fill volume was obtained at 111,196.22 m³, and the cut volume at 5,715.65 m³. This process included stages starting from inputting the measured coordinate data up to the volume calculation using Microsoft Excel with the Average End Area Method, which calculates volume based on the average of the cross-sectional areas of two consecutive sections multiplied by the distance between them.

3.2. Building Information Modeling (BIM) Data Processing

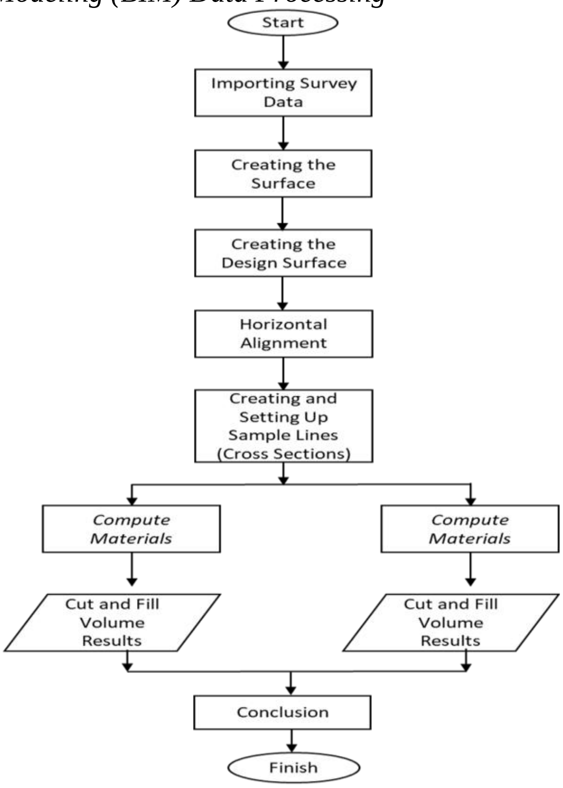

Figure 3 Flowchart of Data Processing Using Civil 3D

Data processing using the Building Information Modeling (BIM) method was carried out within a single software, Autodesk Civil 3D, through the following stages:

Importing Survey Data: Field survey data are imported into Civil 3D as the basis for creating the digital surface model.

Creating the Surface: A three-dimensional contour (3D surface) is generated from the survey points to represent the existing topographic conditions.

Horizontal Alignment: A centerline alignment is created as a reference for the design direction and route.

Longitudinal Profile: A longitudinal section is developed based on the alignment to display ground elevations along the route.

Cross Section (Transverse Section): Cross sections are generated by integrating the surface, alignment, and longitudinal profile. These serve as the basis for automatic cut and fill volume calculations using the Compute Materials and Volumes Dashboard features.

3.3. Building Information Modeling (BIM) Data Processing

The earthwork volume calculation process differs significantly between the conventional and BIM methods. The conventional method uses three separate software AutoCAD, Civil 3D, and Excel with the Average End Area Method. In contrast, the BIM method is fully integrated within Autodesk Civil 3D, from data import to surface, alignment, profile, and cross-section creation, with volume calculations performed using Compute Materials and Volumes Dashboard.

Table 3 Comparison of Cut & Fill Volume Calculations: Conventional Method vs. BIM

Earthwork Item	Conventional Method	Building Information Modeling (BIM) – Civil 3D	
	Average End Area (Conventional)	*Compute Material (BIM)*	*Volumes Dashboards (BIM)*
Cut	5715,65	5894,19	5665,1
Fill	111196,22	112093,61	112038,57

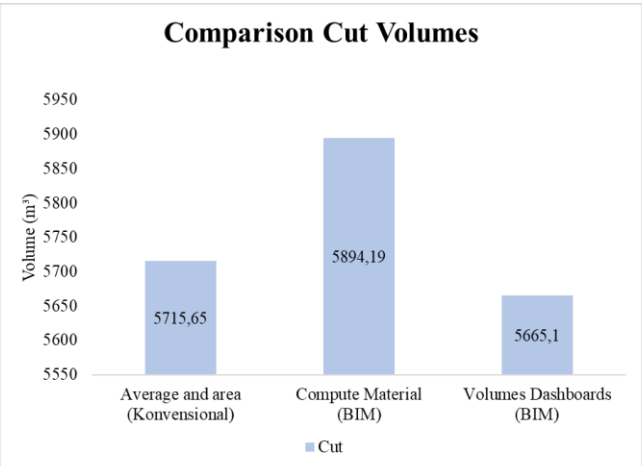

Figure 4 Comparison Chart of Cut Volumes

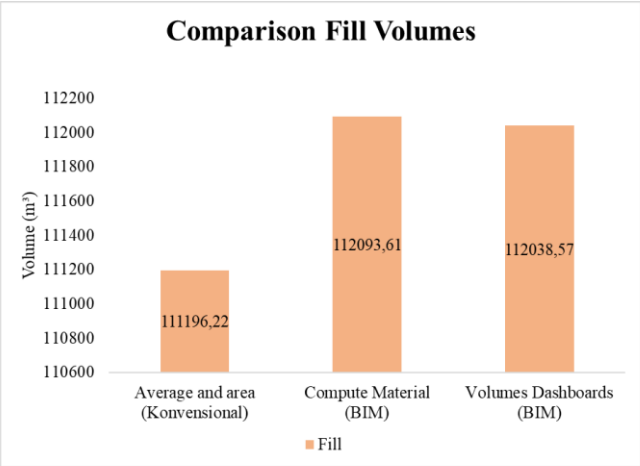

Figure 5 Comparison Chart of Fill Volumes

The deviation analysis of volume calculations was conducted to determine the level of difference between the conventional method and the Building Information Modeling (BIM) method.

$$\text{Deviasi (\%)} = \frac{V_{BIM} - V_{Konv}}{V_{Konv}} \times 100\%$$

Explanation:
V_{BIM} = Volume using the BIM method (m³)
V_{Konv} = Volume using the conventional method (m³)
Deviasi= Percentage difference between the two methods (%)
Results of deviation calculation:

Compute Materials Calculation

a. Pekerjaan galian (*cut*)

$$\text{Deviasi (\%)} = \frac{5{,}894.19 - 5{,}715.65}{5{,}715.65} \times 100\%$$
$$= \frac{178.54}{5{,}715.65} \times 100\%$$
$$= +3.12\%$$

b. Pekerjaan timbunan (*fill*)

$$\text{Deviasi (\%)} = \frac{112{,}093.61 - 111{,}196.22}{111{,}196.22} \times 100\%$$
$$= \frac{897{,}39}{111{,}196.22} \times 100\%$$
$$= +0.81\%$$

Volumes Dashboard Calculation

a. Pekerjaan galian (*cut*)

$$\text{Deviasi (\%)} = \frac{5{,}665.10 - 5{,}715.65}{5{,}715.65} \times 100\%$$
$$= \frac{-50{,}55}{5715.65} \times 100\%$$
$$= -0.88\%$$

b. Pekerjaan timbunan (*fill*)

$$\text{Deviasi (\%)} = \frac{112{,}038.57 - 111{,}196.22}{111{,}196.22} \times 100\%$$
$$= \frac{842{,}35}{111{,}196.22} \times 100\%$$
$$= +0{,}76\%$$

The analysis shows that the volume calculations using the Building Information Modeling (BIM) method have relatively small deviations less than 5% which remain within acceptable technical tolerance limits. From the analysis above, there are noticeable differences between the results of the conventional method and the Building Information Modeling (BIM) method, as follows:

Table 4 Comparison Between Conventional Method and Building Information Modeling (BIM)

No	Comparison Aspect	Metode Konvensional	Metode *Building Information Modeling (BIM)*
1	Software Used	Uses multiple software programs AutoCAD, Civil 3D (for surface contours), and Microsoft Excel for manual calculations.	All processes are carried out within a single integrated software, Autodesk Civil 3D.
2	Volume Calculation System	Uses multiple software programs — AutoCAD, Civil 3D (for surface contours), and Microsoft Excel for manual calculations.	Uses a 3D digital model through the Compute Materials and Volumes Dashboard commands.
3	Data Processing Stages	Conducted separately and manually — from data input, cross-section creation, and volume calculation to recapitulation using different software.	All stages — from data import, surface creation, and profiling to volume calculation — are performed in one integrated workflow.
4	Data Accuracy	Accuracy depends on the number and spacing of cross-sections; input errors can affect results.	Higher accuracy, as the system reads the entire surface data and calculates automatically.
5	Time Efficiency (Cycle Time)	Takes longer due to manual processes and switching between software.	Processing time is shorter because all operations are automated and integrated.

Based on the analysis, there are significant differences between the conventional method and the Building Information Modeling (BIM) method in terms of workflow, accuracy, and time efficiency. The conventional method requires several separate software programs and involves manual processes, making it more time-consuming and prone to errors. In contrast, the BIM method allows the entire process from data import to volume calculation to be performed automatically and integrated within Autodesk Civil 3D. Therefore, the implementation of BIM has proven to be faster, more accurate, and more efficient than the conventional method.

4. Conclusion

The analysis leads to the following conclusions: (a) In terms of calculation results, the conventional method produced an excavation (cut) volume of 5,715.65 m³ and an embankment (fill) volume of 111,196.22 m³. Meanwhile, the BIM method produced excavation (cut) volumes ranging from 5,665.10 to 5,894.19 m³ and embankment (fill) volumes ranging from 112,038.57 to 112,093.61 m³. These differences indicate that the BIM method provides more detailed results that closely reflect actual field conditions, as it calculates based on a fully integrated digital surface model. (b) The comparison of cut and fill volume results shows that the BIM method yields volume values with relatively small deviations from the conventional method—less than 5%. The Compute Materials command resulted in deviations of +3.12% for excavation (cut) and +0.81% for embankment (fill), while the Volumes Dashboard command showed deviations of –0.88% for excavation (cut) and +0.76% for embankment (fill). These small deviation values demonstrate that the BIM method offers a high level of accuracy and that its calculation results are technically acceptable.

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