



# BIM Earthwork Calculation of Open Cut Section of Intercity Railway Based on BIM+GIS technology

Mingliang Pan\*, Hanling Sun

Shenzhen Railway Investment and Construction Group Co., LTD Shenzhen, Guangdong, 518000, China

\*Corresponding author's e-mail: rfvbgt34po@163.com

**Abstract.** To improve accuracy and efficiency, reduce labor intensity and labor costs, this article proposes a earthwork calculation process and method for the open excavation section of the road, which is used to guide the construction of the open excavation section of the road. Based on the research background of the volume calculation of the open cut section of the road in the hilly area of Shenzhen, the basic principle of earthwork volume acquisition is introduced. The concept of BIM+GIS is adopted, and the inclined photogrammetry technology is used to aerial survey the original surface of the open cut section of the road, obtaining a digital surface model (DSM). Using BIM technology to create a roadbed structure building information model, the above two data models are superimposed and fused to obtain a digital engineering model (DEM) for railway roadbed engineering. Then, according to the principle of numerical integration calculation, the volume of the open cut section of the road is quickly obtained. The comparison with traditional methods for obtaining and designing earthwork volume shows that the proposed earthwork calculation method has higher accuracy and faster speed, and can meet the construction needs of road open excavation sections in the hilly terrain environment of Shenzhen area. It has important reference significance for accurately and efficiently obtaining the earthwork volume of road open excavation sections.

**Keywords:** BIM+GIS technology; Intercity railway; Open excavation section; BIM earthwork calculation.

## 1 Introduction

Building Information Modeling (BIM) is the process of using digital models to design, construct, operate, and manage construction projects. The building information model is not simply about integrating digital information. It is an application of digital information that can be used for building design, cost, and management. This method supports the integrated management environment of construction projects, which can significantly improve quality, efficiency, and reduce risks throughout the entire process. Applying BIM technology to earthwork calculation and breaking the shackles of traditional earthwork calculation has become a trend in industry development. Compared to

traditional earthwork measurement methods, BIM technology has been able to accurately and quickly calculate the amount of earthwork filled and excavated in various sites, and is increasingly favored by more and more construction projects[1].

The earthwork calculation of high-speed railway subgrade has the characteristics of large operating area, difficult data collection, high accuracy requirements, and tight construction period requirements. The traditional method involves manual measurement, data collection using a total station or RTKGPS receiver, returning to the office, and drawing a cross-sectional map using CAD software. Based on the cross-sectional method, the earthwork filling and excavation volume is rechecked. During the construction process, a large amount of manual work is still required. The above-mentioned tasks have high labor intensity, high labor costs, are time-consuming and labor-intensive, and require extensive management. In response to these issues, this article adopts oblique photography technology for measurement, combined with the BIM model of high-speed railway design in this area, proposes a earthwork calculation process and method for the open cut section, which is used to guide the construction of earthwork engineering in the open cut section[2-3]. The schematic diagram of earthwork calculation technology route is shown in Figure 1:

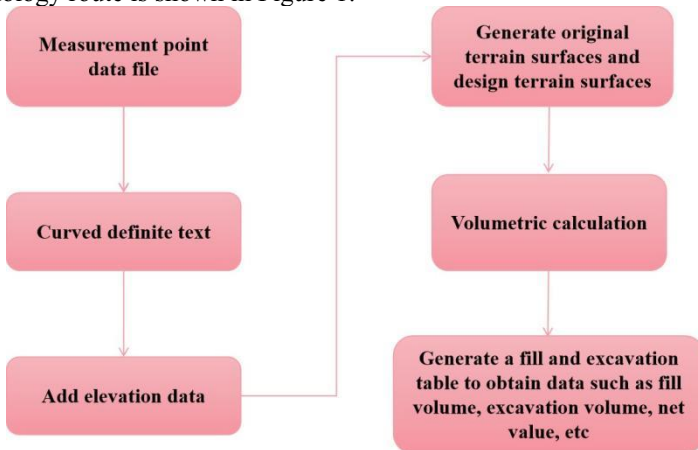


Fig. 1. Schematic diagram of earthwork calculation technology route

## 2 Method

### 2.1 Establishment of Digital Surface Model (DSM)

#### (1) Data acquisition

The aerial camera adopts a vertical takeoff and landing fixed wing unmanned aerial vehicle flight platform, which is equipped with a 5-lens tilt camera to synchronously and automatically collect surface image data from 5 different perspectives (1 vertical direction and 4 tilt directions) according to the planned route. Create a new task based on the designated target area, set parameters such as altitude, heading, lateral overlap

rate, and maximum flight speed. To ensure modeling accuracy, the route design adopts 80% lateral overlap and 70% directional overlap [4].

### (2) Data processing

The data processing uses ContextCapture software for fully automated processing, and generates a three-dimensional model of the real coordinates in the measurement coordinate system through the given control points. The software operation process is: data import → spatial calculation → 3D reconstruction. Due to the large amount of data, to save time and accelerate data processing efficiency, cluster parallel computing mode is adopted for this processing.

### (3) Output of achievements

According to the import format requirements of BIM modeling software OpenRoads, export the produced results into 3MX format. The 3MX data format is a native data format of the Bentley Microstation software platform, seamlessly supporting all software on the Microstation platform, supporting massive data operations, and having strong load-bearing capacity.

## 2.2 Establishment of BIM model

The model of the open cut section of the high-speed railway passenger dedicated line project in the hilly areas of Shenzhen is mainly established using the Bentley series software OpenRoads. This is a professional software designed for infrastructure such as roads, railways, bridges and tunnels, sites, and rainwater pipelines. It is also a BIM platform for the civil engineering industry (embedded with MicroStation, which can integrate models designed by other professional products), providing support for the entire lifecycle of civil engineering and transportation infrastructure projects. Based on the DSM model, BIM software establishes an open cut BIM model suitable for the DSM model by utilizing elements such as road centerline, road edge, or ditch (the process is terrain extraction → route drawing → template editing → generation of open cut section models). These elements can also be random elements of unevenly distributed points or fracture lines (representing interconnected elements in linear segments), such as features in ridges, road edges, and curbs, as well as internal voids or holes representing objects such as buildings and lakes [5].

### (1) Terrain extraction

Due to the high format requirements for terrain models in OpenRoads modeling, it is necessary to use the Bentley series CNCC software to extract terrain models in dgn format (Bentley Universal Format) from the actual model.

### (2) Route drawing

According to the characteristics of linear engineering, it is necessary to draw the centerline of the route for this section of the project. Therefore, first draw the horizontal curve of the route based on the curve element table, and then draw the vertical break line based on the longitudinal section of the route to complete the drawing of the entire route.

### (3) Template editing

Due to the complex terrain and significant fluctuations of this project, the excavation and filling sections and different levels of slopes alternate. Therefore, it is necessary to

create corresponding cross-section templates based on the cross sections of open cut sections with different mileage.

(4) Generate open cut section model

Reference the terrain model file and route file into the open cut section file, activate the terrain, and create open cut section models with an accuracy of 1m intervals based on different mileage sections. The generated BIM open cut section model and fill cut open cut section model are large [6].

### 2.3 Earthwork calculation process and method for open excavation section

Import the GIS terrain model into the BIM model of the route, merge the models, determine the mileage of the cross-section, and export the cross-section. Then, you can perform excavation and fill statistics with one click, and finally obtain the earthwork volume for the open excavation section construction. As shown in Figure 2.

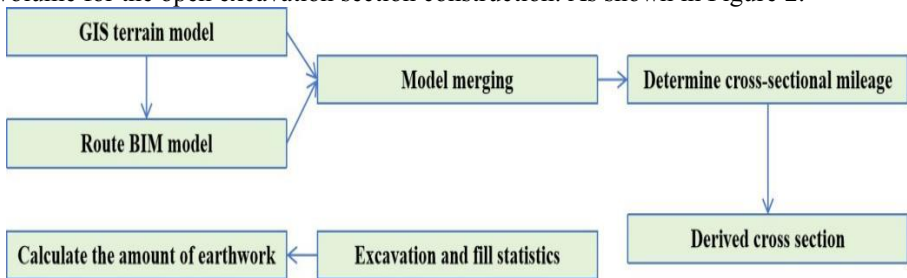


Fig. 2. Earthwork calculation process

(1) Export Cross Sections

Based on the BIM model, using the export section function of OpenRoads, input the mileage, export the corresponding section, and export the specified mileage section according to requirements, or batch export 5, 10, and 20m pile sections according to settings.

Calculate earthwork quantity

Based on the above processes and methods, a method for calculating the earthwork volume of open cut sections based on the BIM+GIS concept is proposed. This method integrates the creation of DTM+BIM models, namely the DEM (digital engineering model) model, and utilizes the component engineering quantity function of Openroads to extract the corresponding mileage segment filling and excavation engineering quantities with one click. In this project, the BIM earthwork calculation for the open cut section is carried out using a 1m interval, and this method is named the BIM method. After inputting the design parameters of the open cut section to the BIM software, the generated volume of the open cut section can be automatically obtained. The actual earthwork volume in this section of the project is 79707.37m<sup>3</sup>.

### 3 Comparison of Cross Section Volume of BIM Open Excavation Section Based on Oblique Photography Technology

Select the section of mileage 209+920-210+100 in the entire route, with a total of 180m open cut section as the experimental section, and compare and analyze the measured excavation area of the open cut section with the actual measurement.

#### 3.1 Comparison of cross-sectional area

According to the comparison of the difference between BIM and design (Table 1), the maximum difference ratio is -6.57%, which is because the cross-sectional area of this mileage is small and the base is too small. The difference is about 1.1m<sup>2</sup>, which can be almost ignored, but it accounts for a large proportion compared to the base. The difference ratio is mostly less than 1%, indicating that the data of BIM and design are basically consistent. The reason for the error may be that the implementation time of the two is different, and there is a difference in vegetation coverage [7].

**Table 1.** Comparison of excavation area of each section

serial number	mileage	Measured area /m <sup>2</sup>	Design area /m <sup>2</sup>	BIM		
				Area /m <sup>2</sup>	Compared with the measured difference/%	Compared with the design difference/%
1	209+920	111.010	122.410	121.662	9.61	-0.62
2	209+940	290.320	312.110	313.871	8.12	0.57
3	209+960	543.880	560.110	567.386	4.33	1.31
4	209+981	840.140	851.810	857.284	2.05	0.65
5	210+000	589.730	585.210	568.072	-3.68	-2.94
6	210+011	355.750	571.110	561.078	57.73	-1.77
7	210+038	666.330	590.410	594.658	-10.77	0.73
8	210+060	256.770	260.510	259.909	1.23	-0.24
9	210+080	93.990	106.510	105.029	11.76	-1.40
10	210+100	10.930	15.810	14.774	35.21	-6.57

According to the comparison of the differences between BIM and actual measurements (Table 1), it can be seen that the difference ratio at mileage 210+011, 210+038, 210+080, and 210+100 is greater than 10%. Among them, the difference ratio at mileage 210+011 is 57.73%. Compared with the actual 3D map and on-site survey, the cross-section is located on the ridge. It is speculated that during on-site measurement, the measurement personnel visually judged the direction of the cross-section to be incorrect, resulting in the measurement not being on the theoretical cross-section, resulting in a large difference and errors. The remaining difference ratios are within 10%. It is speculated that the reason for this error may be that the elevation points collected during the actual measurement were not dense enough, resulting in the later drawing of the cross-section only roughly following the changes in terrain height difference in a

straight line form, ignoring the curvature of the original terrain, and thus unable to accurately reflect the undulating changes of the original terrain arc. In summary, the cross-sectional area obtained by using BIM with inclination is closer to the designed cross-sectional area than measured, and can more accurately reflect the terrain fluctuations during the construction process, thus calculating a more accurate earthwork volume[9].

### 3.2 Comparison and analysis of earthwork volume

The measured and designed earthwork quantities are calculated using the section method. The calculation formula for the section method is: the sum of the two adjacent sections before and after dividing by 2, and then multiplying by the difference in mileage between the two adjacent sections. The number of cross sections should be determined based on the complexity of the design ground and natural ground, as well as the design accuracy requirements. In areas where terrain changes are not significant, fewer sections can be taken. On the contrary, in areas with complex terrain changes and high requirements for design and calculation accuracy, more cross sections should be taken [8].

Taking the earthwork volume of each mileage section in this case as an example (Table 2), the BIM method has a earthwork volume of 77904.795m<sup>3</sup>, the traditional measured method has a earthwork volume of 74178.685m<sup>3</sup>, and the designed and calculated earthwork volume is 77836.44m<sup>3</sup>. According to the principle of section method, the BIM method is in good agreement with the designed earthwork volume, with an error of within 5% compared to the measured earthwork volume. In addition, based on BIM software, the excavation volume can be extracted with one click. The default terrain accuracy set in this experiment is 1m, and the cross-sectional spacing is 1m. The earthwork volume extracted with one click is 79707.41m<sup>3</sup>, with an error of 7.4% compared to the measured earthwork volume[10]. The error inference mainly comes from the inability to accurately remove the covered vegetation. The test flight was conducted in August 2022, and the vegetation was mainly grass with a length of 20-30cm. The vegetation coverage rate within the engineering red line is about 70%.

**Table 2.** Comparison of excavation volume of each mileage section

serial number	mileage	Spacing /m	BIM excavation volume /m <sup>3</sup>	Measured excavation volume /m <sup>3</sup>	Design excavation volume /m <sup>3</sup>
1	209+920	-	-	-	-
2	209+940	20	4355.140	4013.110	4345.010
3	209+960	20	8812.380	8341.810	8722.010
4	209+981	21	14958.835	14532.010	14825.010
5	210+000	19	13540.702	13583.585	13651.510
6	210+011	11	6210.225	5200.040	6359.660
7	210+038	27	15602.176	13797.820	15680.310
8	210+060	22	9400.027	10153.890	9359.910
9	210+080	20	3649.190	3507.410	3670.010
10	210+100	20	1376.120	1049.010	1223.010

## 4 Conclusion

Under the terrain conditions of hilly areas in Shenzhen, oblique photography technology is used to obtain the terrain and establish a BIM model for the open cut section. BIM software can be used to automatically generate the earthwork calculation for the open cut section. The comparative study of the experimental section of this project proves that this method has the advantages of low calculation cost, fast calculation speed, high efficiency, and more accurate calculation accuracy. The entire roadbed of the project adopts oblique photography technology, which has made a clear time plan for the implementation of the project, ensuring the timely progress and completion of the project.

## Acknowledgments

Research on key technology of BIM model derivation of engineering quantity list for intercity railway and urban rail transit. No. (SZDT-JSZX-ZC-2022-008).

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