

Research on Earthwork Allocation Problem Based on Linear Programming Mathematical Algorithm

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Abstract. The calculation of earthwork volume and the rational formulation of earthwork allocation plan are the key links of large-scale engineering construction projects, which are of great significance for reducing the cost of engineering construction projects and saving cost. The traditional earthwork calculation requires not only a large amount of human resources and time, but also a large calculation error between the calculated earthwork volume and the actual. This paper mainly introduces the basic ideas based on Civil 3D earthwork calculation method and how to solve the problem of earthwork quantity allocation by means of operational planning linear programming mathematical model, and verify the feasibility of mathematical model to solve the problem of earthwork quantity allocation through engineering examples. Finally, the plan of the earthwork allocation plan is drawn, which is convenient for the construction enterprise manager to make earthwork construction decision and formulate the earthwork construction plan in line with the actual project. The analysis shows that: Civil 3D software is used to assist the calculation of earthwork volume with high efficiency and accurate results. It is feasible to solve the problem of earthwork allocation by using linear programming mathematical model.

Introduction

The "13th Five-Year Plan" pointed out that the state should speed up the pace of new urbanization construction and accelerate the construction and development of urban agglomerations. It is necessary to improve the infrastructure system of modern cities and implement green planning, design and construction standards based on the resource and environmental carrying capacity [1]. Therefore, the development plan of the construction industry in the next five years will also focus on the direction of urbanization [2]. However, the construction cost of large-scale engineering construction projects often amounts to tens of millions of yuan or even 100 million Chinese yuan. Cost control is a major problem encountered by most enterprise managers at present. Seeking to solve the cost control measures has become a breakthrough in reducing costs and cost [3]. As the primary stage of engineering construction, earthwork engineering, in the high-investment engineering construction project, the ratio of the cost of earthwork engineering to the total cost can not be ignored, and determines the profit level and management level of the project. It is a reference indicator for controlling costs. Inaccurate calculation results of earthwork and unreasonable earthwork allocation plan will not only affect the construction progress of the project, but also delay the construction period, and will also increase the investment of the project [4]. In order to reduce the cost of engineering construction projects, save cost, accurately calculate the amount of excavation and earthwork of the project, and formulate and arrange a reasonable earthwork allocation plan after considering various influencing factors, it is especially important for the project manager. This not only serves as the basis for managers to make decisions, but also becomes a major measure to effectively control construction costs and ensure smooth construction and shorten the construction period.

Earthwork Calculation Method Based on Civil 3D

There are many softwares for realizing site visualization on the market, but there are relatively few softwares that have earthwork calculations. For example: Revit realizes the 3D visualization of the building model; InfraWorks realizes the visualization of the site model, but can not calculate the

amount of earthwork; Civil 3D realizes the functions of site visualization and earthwork calculation, and is used by most enterprises for earthwork. Auxiliary tools for volume calculations.

Civil 3D is a 3D design software developed for the civil engineering industry. It is based on the AutoCAD platform and has good interoperability. It has certain advantages in civil engineering applications. At the same time, Civil 3D software provides convenient and quick design tools for topographic survey and mapping and earthwork calculation. Especially in the calculation of earthwork volume, according to the topographical measurement data, using Civil 3D to create a three-dimensional terrain model before and after design, and adjusting the design parameters, the software can automatically calculate the amount of earthwork, and provide accurate planning for a reasonable earthwork allocation in the later stage. The amount of earthwork.

Civil 3D aided design software calculates the amount of earthwork by comparing the original terrain surface created by the original terrain data with the designed terrain surface, and then using the volume formula of the software to calculate the volume of the two surfaces. During the creation of the original terrain surface, Civil 3D software can create the original terrain surface through various data types, such as the terrain elevation data obtained by the real measurement, the terrain contour data, and the terrain 3D feature line data. The process steps of the software to calculate the amount of earthwork are as follows (take the 6# floor of a project as an example):

(1) Create the original terrain surfaces and design terrain surfaces. When creating the original terrain surface and designing the terrain surface, you need to create a surface object in the Civil 3D software, then add the terrain feature data to the created surface through the surface definition. Finally, the software automatically recognizes the terrain parameters and generates Corresponding terrain surface.

(2) Edit the terrain surface. This process mainly judges the accuracy of the original data through the generated visual terrain. If there is a large difference in the local terrain, it is considered that there is a large error in the local elevation point. The elevation point should be adjusted and the surface should be regenerated by the editing function of the surface. , reduce the late calculation error.

(3) Calculate the earthwork volume. In the calculation of the earthwork volume, in the same area of the Civil 3D software interface, the original terrain surface model and the designed terrain surface model are solved by the volume calculation tool in the software surface analysis panel. By selecting and comparing the volume difference between the two surfaces, the software automatically calculates the amount of earthwork to be excavated.

Earthwork Quantity Allocation Method

Implementation of the Technical Route. Before the construction of the project construction, the corresponding cost plan should be formulated. The traditional practice is mainly that the enterprise managers make corresponding decisions based on the construction experience, lacking a reasonable basis, and ultimately lead to an increase in the construction period and cost, and it is difficult to obtain satisfactory results. Considering the significant cost of earthwork engineering, it determines the profitability and management level of the entire project. In order to reduce the cost of engineering construction projects, save cost, accurately calculate the amount of earthwork, a reasonable earthwork allocation plan is of great significance to the project. To this end, after the earthwork quantity has been accurately calculated, the earthwork is regarded as the management problem of operations research. A reasonable mathematical model is established by using linear programming of operations research, and the mathematical model is solved. Finally, according to the obtained model, solve the formulation plan for earthwork quantity for enterprise managers to make earthwork management decision. The technical route of using the principle of operations research to realize the amount of earthwork engineering is shown in Figure 1.

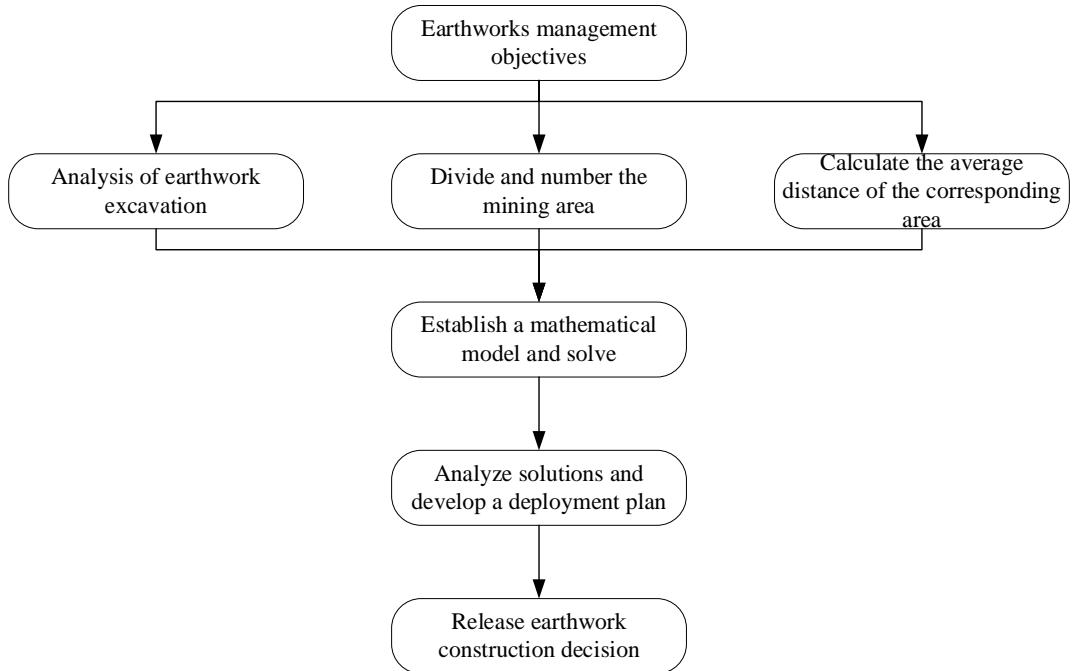


Figure 1 Earthwork quantity allocation technical route

Mathematical Model of Earthwork Quantity Allocation. Before using the linear programming of operations research to establish a mathematical model, firstly propose the objective function according to the problems that the enterprise manager needs to solve, to maximize or minimize the objective function, then define the constraint to establish the objective function constraints quantitatively, and finally use the mathematical method to solve mathematical model. In the process of earthwork quantity allocation, the objective function based on the distance between the distance and the earthwork is established, that is, the sum of the product of the earthwork and the corresponding distance, taking the minimum value.

Consider that there are n excavation areas and m fill areas in the site of the project construction project, using i, j to indicate the number of the excavation area and the fill area respectively; c_{ij} means the distance from the i -th excavation area to the j -th fill area; x_{ij} represents the amount of earthwork from the i -th cut area to the j -th fill area.

The objective function Z is:

$$Z = \sum_{m=1}^m c_{1m}x_{1m} + \sum_{m=1}^m c_{2m}x_{2m} + \dots + \sum_{m=1}^m c_{nm}x_{nm} \quad (1)$$

The constraints are:

$$\left\{ \begin{array}{l} x_{11} + x_{12} + \dots + x_{1m} = a_1 \\ x_{21} + x_{22} + \dots + x_{2m} = a_2 \\ \dots \\ x_{n1} + x_{n2} + \dots + x_{nm} = a_n \\ x_{11} + x_{21} + \dots + x_{n1} \leq b_1 \\ x_{12} + x_{22} + \dots + x_{n2} \leq b_2 \\ \dots \\ x_{1m} + x_{2m} + \dots + x_{nm} \leq b_m \end{array} \right. \quad (2)$$

Where $x_{ij} \geq 0, i = 1, 2, \dots, n, j = 1, 2, \dots, m$.

Case Study

The case project is a master plan for a college. The first phase covers an area of about 20 ha and the

total construction area is about 7.6 ha. The main construction contents include the teaching area, dormitory area, dining area, library, sports activity center and supporting infrastructure. The overall scale of the project is huge, the building shape and construction process are complex, the project is built by mountains and waters, the terrain is high and low, the original landform is complex, the geological conditions are poor, and the earthwork is excavated and filled. According to the basic characteristics of the project, in the calculation of earthwork volume, the traditional calculation method not only consumes a large amount of manpower and material resources, but also the accuracy of the calculated results is not high, and it is difficult to meet the calculation cost of the project later. In order to achieve financial and material savings, fast and accurate results, the project manager decided to adopt the Civil 3D software platform that is currently widely used in earthmoving. The software calculation results are shown in Table 1.

Table 1 Summary of single earthwork volume

No.	Name	Earthwork volume (m ³)		
		Total excavation	Total fill	Remaining earthwork
1	1# Building	76486	3812	72674
2	2# Building	41078	27239	13839
3	3# Building	38748	37716	1032
4	4# Building	40066	837	39229
5	5# Building	0	152077	-152077
6	6# Building	11718	6461	5257
7	7# Building	51113	0	51113
8	8a1# Building	17325	42690	-25365
9	8a2# Building	7317	39701	-32384
10	8b# Building	15407	33308	-17901
11	8c# Building	6873	44783	-37910
12	9a# Building	15561	11278	4283
13	9b# Building	10265	7699	2566
14	9c# Building	12942	17192	-4250
15	10# Building	3213	3890	-677
16	11a# Building	16731	4789	11942
17	11b# Building	5111	0	5111
18	11c# Building	3796	0	3796
19	11d# Building	4699	0	4699
20	11e# Building	5865	36	5829
21	12# Building	22682	2950	19732

Before formulating the earthwork allocation plan according to the amount of earthwork, it is necessary to formulate the basic principles of earthwork deployment. Firstly, try to keep the balance of earthwork and excavation and filling, reduce the number of repeated dumping and mechanical shifts; secondly, rationally divide the blending area to avoid local imbalance caused by unreasonable partition; then ensure that the transport volume and the corresponding transport distance reach to some extent Minimal to reduce transportation costs, thereby reducing engineering costs; Finally, select the appropriate deployment route, plan and manage transportation equipment to ensure its efficient operation in the field.

(1)According to the existing earthwork quantity data, calculate whether the amount of excavation work and the amount of fill work are balanced. If it is not balanced, calculate the amount of earthwork that needs to be spoiled or borrowed. In this example, the excavation amount is calculated to be 241102 m³, the fill amount is 270564 m³, and the borrowing soil needs to be borrowed 29462 m³. The final earthwork volume of each unit in the field is shown in Table 1 (“+” indicates the amount of earthwork required to be shipped out of the area if it meets the requirements

of its own filling; “-” indicates that the area cannot meet its own filling. The amount of filling required to be transported from other areas under the request).

(2) In order to make the deployment plan clear, and also to facilitate the establishment of mathematical models in the later stage, it is necessary to number the area within the field. In this example, the numbering is mainly based on the amount of earthwork in each area. The cut area number is W_i and the fill area number is T_j . In addition, due to the imbalance of excavation and filling, it is necessary to borrow land, so define a borrowing area J .

(3) According to the objective function expression in the mathematical model, it is necessary to determine the transportation distance of the corresponding area. In order to make the calculation convenient and minimize the error, the latter calculates the transportation distance as the calculated reference value. The transportation distance calculated according to the road plan is shown in Table 2.

Table 2 Earthwork volume and distance (Unit: m^3)

Excavation area	Filling area							Total amount of earth excavation
	T_5	T_{8a1}	T_{8a2}	T_{8b1}	T_{8c}	T_{9c}	T_{10}	
W_1	168	1030	490	950	390	890	591	72674
W_2	435	1034	653	854	432	942	299	13839
W_3	250	703	462	612	62	562	462	1032
W_4	225	853	313	763	213	422	605	39229
W_6	335	691	516	781	673	222	805	5257
W_7	600	570	793	660	693	197	1065	51113
W_{9a}	1125	70	610	160	710	399	891	4283
W_{9b}	638	549	865	639	765	80	947	2566
W_{11a}	665	891	520	801	446	957	70	11942
W_{11b}	613	798	427	708	454	965	256	5111
W_{11c}	653	758	387	668	494	1005	296	3796
W_{11d}	713	698	327	608	554	1065	343	4699
W_{11e}	763	648	277	558	367	1115	293	5829
W_{12}	785	711	340	621	440	1137	110	19732
J	-	-	-	-	-	-	-	29462
Total fill	15207	25365	32384	17901	37910	4250	677	270564

(4) Solve the mathematical model and get the deployment plan. The results of the solution are shown in Table 3. The data in Table 3 clarifies the relationship between the excavation area and the earthwork volume of the filling area. For example, the $72674 m^3$ generated by the 1# building and the $13839 m^3$ earthwork generated by the 2# building can all be transported to the 5# building for backfilling. Further analysis of the data in the Table shows that the 5# building needs to be backfilled with $152077 m^3$ of earthwork, but the total fill of the 1#, 2#, 4#, 6# and 7# buildings is $140516 m^3$. Can not meet the backfill of the 5# building, the difference between the two is $11,561 m^3$, and the 8b# floor needs to backfill the $17901 m^3$ earthwork, but the sum of the fills provided by all the monomers is 0, indicating that the 8b# building needs all the nearby borrowing. This indicates that it is necessary to borrow the $11561 m^3$ earthwork to backfill the 5# floor and the $17901 m^3$ earthwork backfill 8b# building. The sum of the borrowed earth amounts is exactly the same as the previously required amount of land borrowed $29462 m^3$.

(5) According to the calculation results, draw the earthwork plan plan.

Table 3 Calculation results of earthwork quantity allocation (Unit: m³)

Excavation area	Filling area							Total amount of earth excavation
	T_5	T_{8a1}	T_{8a2}	T_{8b1}	T_{8c}	T_{9c}	T_{10}	
W_1	72674	0	0	0	0	0	0	72674
W_2	13839	0	0	0	0	0	0	13839
W_3	0	0	0	0	1032	0	0	1032
W_4	20399	0	0	0	18830	0	0	39229
W_6	5257	0	0	0	0	0	0	5257
W_7	28347	21082	0	0	0	1684	0	51113
W_{9a}	0	4283	0	0	0	0	0	4283
W_{9b}	0	0	0	0	0	2566	0	2566
W_{11a}	0	0	0	0	11265	0	677	11942
W_{11b}	0	0	0	0	5111	0	0	5111
W_{11c}	0	0	3796	0	0	0	0	3796
W_{11d}	0	0	4699	0	0	0	0	4699
W_{11e}	0	0	4157	0	1672	0	0	5829
W_{12}	0	0	19732	0	0	0	0	19732
Total fill	15207	25365	32384	17901	37910	4250	677	270564

Conclusion

In this paper, based on the characteristics of wide excavation area, large amount of excavation and complex terrain, and the accurate calculation of earthwork volume based on Civil 3D software, the mathematical model of multivariate and multi-constraint conditions is established through operation research to solve the problem of earthwork quantity allocation. The practice of the example shows that the calculation efficiency is fast and the calculation accuracy is high based on the calculation of Civil 3D software. According to the mathematical solution analysis, the earthwork quantity allocation plan is formulated, and finally the earthwork quantity planning plan is provided to the enterprise manager for decision making, which has a good application effect and has certain reference value for similar engineering projects.

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