IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

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To cite this article: Dahua Li *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **218** 012024

The Study on the Earthworks of Green Construction based on Value Engineering

Dahua LI [1*], Zhihao Li[2] and Ziguang Zhang[1]

[1] School of Civil Engineering, Anhui Jianzhu University, Hefei 230601,China;

[2]The Architecture Design & Research Institute of Zhejiang University Co. Ltd,310012, Hangzhou,China

[*]Corresponding author's e-mail: ldh2006a@163.com

Abstract. Earthwork construction brings many phenomena like the destruction of the natural structure of the land, the damage of the surface vegetation and soil exposed etc. These phenomena result in numerus environmental problems, such as dust pollution and soil erosion. Therefore, during the period of earthwork construction, it is practically meaningful to implement the concept of Green Construction, establish a scientific evaluation system for Green Construction, evaluate the Green Construction degree of each construction plan. This paper use two concepts, Value Engineering Theory and Analytic Hierarchy Process to create a Green Construction evaluation system basing on Value Engineering. Furthermore, the paper takes the earthwork of transportation and leveling construction for a real the large-scale grid conversion station as an example to illustrate the method of calculating the value coefficient of each Green Construction project and the decision optimization process for multiple value coefficient based construction schemes.

1.Introduction

Earthwork construction always involves cutting, transiting and filling of earth rocks. Those works might cause many environmental problems such as Vegetation destruction, Soil exposed and unbalance of Groundwater. As the result of these problems natural disasters, such as poor air condition, soil erosion and debris flow, can occur. Therefore, it is significative to implement the green construction concept at earthwork construction, especially at large scale site formation works. Power transmission from West China to East China is a national policy in China, which rationally allocates domestic energy resources and electric load. This policy requires to build several world's top long feed line of power distribution systems. During the construction process of these systems, the central problem will be how to better carry out Chinese Five Development Concept on the earthwork construction of those large power plants and maximise the value coefficient of green construction.

The present domestic green construction standards are an evaluation system which only includes qualitative indicator, but it lacks the quantitative indicator to critic green construction scheme. In recent years, researchers have tried to rebuild the evaluation system for green construction from different aspects. For instance, Xue Song created an evaluation system based on fuzzy-matter-element theory after coordinating the influences from design, construction and completion on green construction. Shen Qiyu and his team establish a new evaluation system and an evaluation method for green construction by combining Analytic Hierarchy Process and System Engineering Theory.

The goal of this paper is to maximize the green construction value coefficient. The methods of the research include Analytic Hierarchy Process and Value Engineering Theory. The result of the study is the methods of building green construction evaluation system based on Value Engineering. The achievement will be practiced as a reference to optimize green construction plan on the earthwork construction of the largest building grid converter station in China.

2. The Concepts of Value Engineering and Green Construction

2.1 Value Engineering

Value engineering (VE) is a systematic method to improve the value of research object. By adjusting the function and the cost of research objects and increasing the ratio of object's function to cost., the production and management can be optimized. The two important factors which define the value of research objects are function and cost. The value of the research object can be expressed as a formula below.

$$V = F / C \qquad (1)$$

In the formula, V F and C represent Value, Function and Cost respectively. Depending on formula 1, The value of the research object in practical cases can be increased from two aspects. (1) improving or maintaining the function and reducing the production cost by technological innovation. (2) significantly cutting the costs of productions by removing nonvalue or less-value function.

The green construction evaluation system which involves value engineering theory is based on the green construction evaluation indicator system. The function of the system is to select the maximum value coefficient of green construction. It considers each objective of green construction as the function of research objects （F_i）, the costs of different green construction schemes as the cost of research schemes (C_i) and the value coefficients (V_i) of various construction schemes as evaluation indicator. Basing on the formula 1 of VE, we can deduce that the value coefficient of green construction scheme can be expressed as,

$$V_i = F_i / C_i \qquad (2)$$

The C_i in the formula 2 can be calculated by the formula,

$$C_i = \frac{c_{ij}}{\sum c_{ij}} = \frac{a_{ij} + b_{ij} + d_{ij} + e_{ij}}{\sum\left(a_{ij} + b_{ij} + d_{ij} + e_{ij}\right)} \qquad (3)$$

In the formula, c_{ij} refers to one of the multiple sub-project green construction schemes. a_{ij}, b_{ij}, d_{ij} and e_{ij} represent the labor cost, material cost, machinery cost and other expenses of the scheme, respectively.

2.2 The Concept of Green Construction

Engineering construction is the process of building the structure depending on an abstract design drawing. In the meantime, it also relates to vast resources exchange between human and nature. In the process of construction, human constantly consume the energy and resources from nature to create the structure they need, while producing exhaust gas and waste to the environment. In order to build resource-friendly and environment-friendly society, in the process of construction, the amount of hazardous waste and exhaust gas produced should be decreased. In this case, relevant scholars proposed the concept of green construction.

Green Construction concept emphasizes the dynamic integration of green management, environmental protection and sustainability of resources. This concept is more scientific and environmentally friendlier than the concepts of technology innovation, dust removal, water sprinkling and closed management on traditional construction process. Green Construction requires that scientific management and technological innovation go through the entire construction process to achieve four conservations and one protection. This requirement minimizes the waste emission and pollution of

IOP Conf. Series: Earth and Environmental Science 218 (2019) 012024 doi:10.1088/1755-1315/218/1/012024

construction process.

3. Scheme Analysis based on Value Engineering Coefficient

3.1 The Principle of Green Construction Evaluation

Green Construction Evaluation System should keep up with the development of science and the trend of the times as well as should meet the needs of the construction process in a certain period. Thus, the system needs to meet the following four basic principles [4-6].

(1) Sustainability. The evaluation system should be guided by resource conservation and environmental protection rules, follow the principle of sustainable development, and fully consider the carrying capacity of the natural environment, in order to balance development and constraints in the construction process.

(2) Scientific and systematic. The framework of the evaluation system should be scientific and systematic. Therefore, the scientific indicator design, systematic factors, and the interactive relationship between upper and lower factor layers are required.

(3) Quantifiable. Except the qualitative indicators included in the evaluation system, the indicators should be quantifiable as well. The quantified evaluation system can truly and clearly reflect the advantages and disadvantages of different green construction schemes.

(4) Dynamic orientation. the construction of a project is a dynamic process. The dynamic is mainly reflected by renewal of technology and changes in the requirements of the functions of the building (structure), and so on. Therefore, the evaluation indicator should also be dynamically adjustable and provide feedback for adjustment based on development needs.

3.2 the steps of optimizing Green Construction Scheme based on Value Engineering

The green construction evaluation system based on value engineering does not only includes the complete and scientific green construction indicator system, but also adopts the value coefficient as the main evaluation indicator. The steps for establishing the system are as follows:

(1) Building a structured indicator framework. The indicator framework should follow the four basic principles created by the evaluation system. The framework mainly consists of four levels, the target level A, the criterion level B, the indicator level C, and the factor level D.

(2) Determining the weight of the indicator. By questionnaire survey, consulting relative importance of each indicator from relevant experts, scholars, and on-site construction personnel.

(3) Using a Nine-level Scale Method to construct a decision matrix.

(4) Checking the consistency of the decision.

(5) Calculate the overall weight of each scheme, which will be the function coefficient.

(6) Calculate the value function coefficients of each scheme.

3.3 Establishing Decision Matrix

The structure of build decision matrix by Nine-level Scale Method is showed as below [7, 8].

$$
\begin{array}{c}
 \\ d_1 \\ d_2 \\ \vdots \\ d_n
\end{array}
\begin{array}{c}
\begin{array}{cccc} d_1 & d_2 & \cdots & d_n \end{array} \\
\begin{bmatrix}
q_{11} & q_{12} & \cdots & q_{1n} \\
q_{21} & q_{22} & \cdots & q_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
q_{n1} & q_{n2} & \cdots & q_{nn}
\end{bmatrix}
\end{array}
$$

As to a certain indicator c_i which is inside the indicator layer C contains n factors in total. Its decision matrix can be expressed as:

In the matrix, q_{ij} donates the degree of importance of $d_i(i=1,\cdots,n)$ factor which is the j-th factor of i-th row compared to other factors in this row. The value of q_{ij} can be 1, 3, 5, 7 or 9 which correspond equally important, slightly important, obviously important, strongly important, and extremely important. When the degree of importance is between the above five level, the value of q_{ij} can be assigned to 2, 4, 6 or 8.

3.4 Consistency Test

The process of calculating is showed below.

(1) Calculating the eigenvalues of the matrix by using the eigenvectors of the Decision Matrix.

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{FW_i}{W_i} \quad (4)$$

(2) Calculating the consistency indicator CI by evaluating the eigenvalues of the Decision Matrix.

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (5)$$

(3) Calculate the random consistency ratio CR by using the consistency indicator CI and the average random consistency indicator RI .

$$CR = \frac{CI}{RI} \quad (6)$$

The value of RI can be found in Table 1.

When calculation result shows that $CR \le 0.10$, it can be considered that the Decision Matrix can pass the consistency check, otherwise the weights of the Decision Matrix features should be re-determined and the above consistency check steps should be repeated until the consistency check is passed [12-15].

Table 1. Average random consistency index value

n（number of steps of the Matrix）	2	3	4	5	6
RI	0.00	0.58	0.90	1.12	1.24

3.5 The Function and Cast Coefficient Calculating of Each Schemes

We assume that there are n green construction plans in total. So, the factor of a certain factor in different plans can be expressed as below.

$$F_i = \omega_{B_i} \cdot \omega_{C_i} \cdot \omega_{D_i} \quad (7)$$

ω_{B_i} , ω_{C_i} and ω_{D_i} are referred to the weight of principles, indicators and factors respectively.

If M as a cost of a green construction scheme is the sum of construction labor costs, material costs, machinery costs and other expenses for the scheme, the construction cost coefficient for the n-th green construction scheme can be expressed as below.

$$C_i = M_i / \sum_{i=1}^{n} M_i \quad (8)$$

3.6 Scheme Optimization

Substituting the function coefficients and construction cost coefficients of each schemes into formula 2, the value coefficients of each schemes can be obtained. Those value coefficients reflect in the degree of matching between function and cost in each program. A higher value coefficient indicates that the program can gain the maximum functional effect with a reasonable amount of cost. By comparing the value coefficients of each scheme and selecting the scheme with the largest value coefficient, the green construction scheme can be optimized based on value engineering.

4. Engineering Applications

4.1Project Overview

The power grid conversion station is located in the Jingtingshan area in Xuancheng City, Anhui Province, and has a hilly terrain. The project occupies an area of 38.02 hm2 and the amount of earth and stone works is about 258×104 m3. Since the base is surrounded by ecologically reserve, transporting earth and stone will be extremely difficult. In order to furthest protect the surrounding ecological environment and reduce the pollution caused by construction, it is an urgent problem how to optimize the green construction scheme under the premise that the construction cost will not be greatly increased. When the project department formulated the special scheme for green construction of the project, they collaborated with experts to select the scheme with the largest value coefficient for implementation. The methods were analyzing and valuating the value coefficients from various schemes with different evaluation indicator. This process shows how to apply the research results, green construction evaluation system based on value engineering to practical projects.

4.2 The Structure and the weight of evaluation indicators

According to the engineering construction needs, the evaluation indicator system is divided into four levels and the evaluation indicator framework is shown in Figure 1. The questionnaire survey was used on-site for the assessment. A total of 35 questionnaires were sent and 32 valid questionnaires were received. According to the results of the survey, the relative importance of indicators at each level was determined, and a Decision Matrix was constructed based on the 9-level scale method.

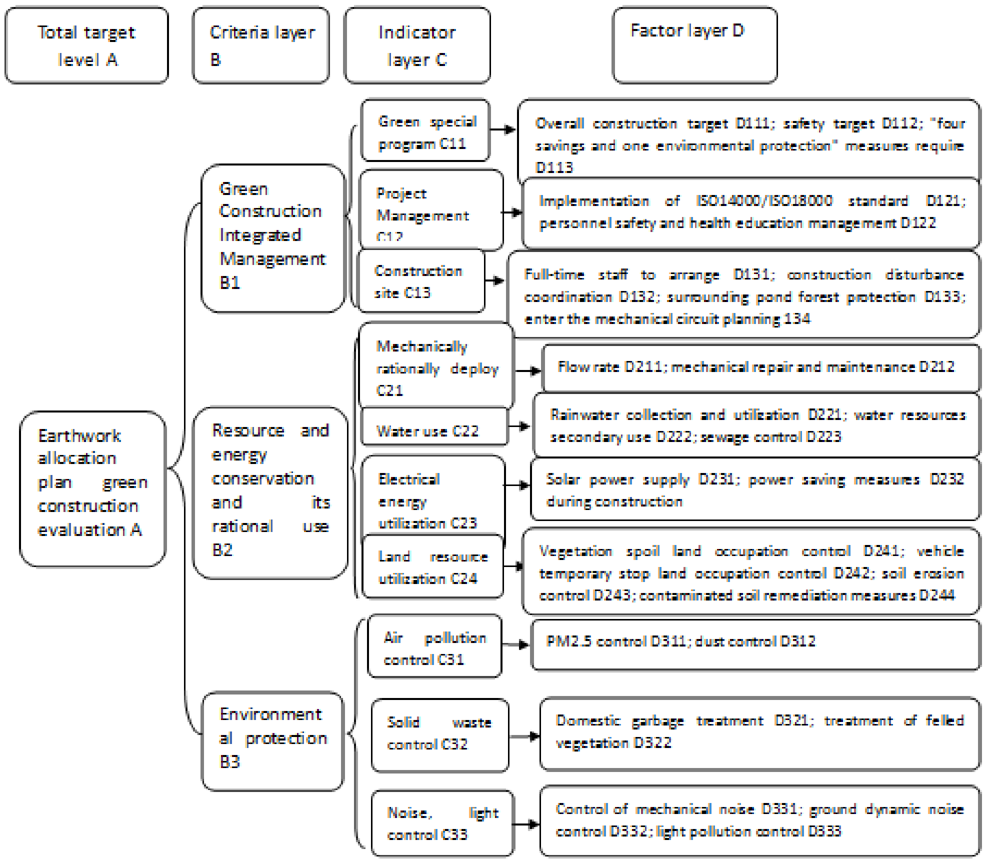

Fig. 1. The frame of evaluation indicator

This paper only describes the calculation and evaluation process of evaluating the water utilization on the green construction of Jingtingshan converter station. Since the project is located in remote mountainous areas, urban water supply network can reach there by the end of September, but the clients require the site leveling project to be completed by the end of August based on the contract. Therefore, the problem for construction water supply must be solved on-site during the earthwork construction period. According to the actual situation of the construction site, three sets of green construction schemes were designed.

Option 1, due to the abundant rainwater in the mountainous area, it was decided to reinforce and increase the height of the on-site two ponds and install a rainwater collection device.

Option 2, Purchasing and installing the Sewage re-purification secondary use equipment on the site.

Option 3, taking wells at the construction site to collect water.

The relevant indicator weights and scheme costs are shown in Tables 2-5.

Table 2. The weight and CR value of D22

Indicator Project	$D221$	$D222$	Weight
$D221$	1	1/5	0.167
$D222$	5	1	0.833
$\lambda_{max}=3.109$， $CI=0.0545$， $RI=0.58$， $CR=0.094$			

Table 3. The weight and CR value of C22

Indicator Project	$C21$	$C22$	$C23$	$C24$	Weight
$C21$	1	3	1/5	1/5	0.177
$C22$	1/3	1	1/5	1/5	0.575
$C23$	5	5	1	3	0.095
$C24$	5	5	1/3	1	0.153
$\lambda_{max}=4.26$， $CI=0.087$， $RI=0.9$， $CR=0.097$					

Table 4. The weight and CR value of B2

Indicator Project	$B1$	$B2$	$B3$	Weight
$B1$	1	3	3	0.143
$B2$	1/3	1	1/3	0.571
$B3$	1/3	3	1	0.286
$\lambda_{max}=3.109$， $CI=0.0545$， $RI=0.58$， $CR=0.094$				

Table 5. Cost statistics for each program

Cost	Scheme #1	Scheme#2	Scheme#3
Labor（million）	0.56	1.32	1.80
Material（million）	1.89	4.49	6.30
Machinery (million)	/	/	/
Other Expense (million)	/	/	/
Sum (million)	2.45	5.81	8.10

Based on equation 7, the functional coefficients of the three sets of schemes are: 0.50, 0.80, and 0.42. From the formula 8, the construction process cost coefficients for the three sets of schemes are: 0.150, 0.355, and 0.495. By substituting the above function coefficient and construction process cost coefficient into formula 2, the value engineering coefficients of the three sets of schemes are: 3.33, 2.25, and 0.85. Considering the calculation results, it can be seen that the value coefficient of the first scheme is the largest, not only the construction cost is low, but also the green construction can be realized to the greatest degree. The second set of construction costs are moderate. The value coefficient of it is not as obvious as the one in first scheme. The third set of schemes does not only have a higher construction cost but also gain a smaller value coefficient, which means that the higher cost has comparably less green construction effect. As a result of this, it has been explored that the first set of schemes is the best.

5. Conclusion

This paper studies the method of establishing a green construction evaluation system based on value engineering and illustrates the calculation methods used on the earthwork construction of the largest grid conversion station which is currently under construction in China. The results of previous study show that the optimization methods of value engineering based green construction scheme can be applied to optimize the green construction scheme of earth and stone works quickly and efficiently. The method comprehensively considers the balance between the cost and effect of green construction and can quickly select the construction scheme which has low cost and maximal benefit from sets of green construction schemes. Wide applicable range and high practical value of this method demonstrates that it can be used as a reference for the decision-making of green construction schemes.

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