Analysis and impact of construction environment on the project cost

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Abstract. From the construction environment point of view, the evaluation index system was established, using the set pair analysis method, evaluation on project cost effect model based on the construction environment was built, and an example was given to analyze the factors influencing the construction cost, providing reference basis for engineering cost control.

1. Introduction

The project is specific to the project construction as the goal and is a one-time job which construction enterprises complete under certain conditions[1]. The project cost refers to the sum of all the costs that enterprise uses for construction and management [2], it reflects the consumption of labor and material of the engineering synthetically.

2. The evaluation index system of construction environment on project cost

Reducing cost of the project reasonably is a basic work target in engineering construction. The engineering cost includes indirect costs and direct costs. Indirect cost refers to the total expenditure of construction preparation and management, also including the necessary expenses incurred in engineering construction, such as maintenance costs, material consumption, travel expenses and utilities. Direct cost refers to the cost of the engineering entity in engineering construction and various expenses that in favor of the project entities, which can be included in engineering cost directly. In addition, the construction cycle and the occurrence of material engineering cost are also important factors which have an important impact on the project cost [3]. These cost varies with the construction itself and the internal and external state of the construction enterprise, such as the nature of engineering, construction condition, enterprise technical conditions, the degree of mechanization, construction organization and the lifting of construction materials prices and so on, they all affect project cost directly [4].Whether the construction scheme is advanced and feasible and whether technical and organizational measures is reasonable determine the level of the project cost to a great extent. Finding out the key influence factors will lay the foundation for us to find ways to reduce project cost. In this paper, from five aspects of the construction organization plan, construction period, construction quality, construction safety and construction site management, construction of evaluation index system of the project cost is established, we can see in table 1.

Tab.1. The evaluation index system of construction environment on project cost

First class index	Second class index	Third class index
construction environment of evaluation index system of the project cost A	the construction organization plan C_1	Construction method x_{11}
		Construction machinery and equipment x_{12}
		Construction organization x_{13}
		Construction sequence arrangement x_{14}
		Site layout x_{15}
	construction period C_2	The influence of the relevant units x_{21}
		The change of construction conditions x_{22}
		The technical level and error occurred x_{23}
		The level of construction management x_{24}

		The occurrence of accident x_{25}
	construction quality C_3	Technology and management personnel x_{31}
		Control of material x_{32}
		Control of Mechanical x_{33}
		Construction environment x_{34}
	construction safety C_4	The scene security measures x_{41}
		Personnel safety training x_{42}
		Emergency rescue investment x_{43}
	construction site management C_5	Hydropower and communication arrangement x_{51}
		Roads and drainage system x_{52}
		The position of material and equipment x_{53}
		Cross operational site arrangement x_{54}
		Setting and location of housing and productive house x_{55}

3. Evaluation model of construction environment on project cost

3.1 Evaluation model of the third class index of construction environment on project cost

Suppose the panel aggregation who participate in the evaluation of construction environmental indicators of the is $D=\{d_1,d_2,\cdots d_z\cdots d_g\}$,the second class evaluation index of construction environment is $C=\{C_1,C_2,\cdots C_k\cdots C_5\}$. The maximum score on each index is q and the score will be higher if the index has more influence on project cost. The third class index of construction environment on project cost is $X=\{x_{k1},x_{k2},\cdots x_{kt}\cdots,x_{\mathrm{ks}}\}$. The evaluation matrix which constructed of the Zth groups of the panel on the second level of evaluation indexes of the third level evaluation index is presented in formula (1).

$$M_Z=\begin{bmatrix} m_{1k1}\ m_{1k2}\cdots\ m_{1kt} \\ m_{2k1}\ m_{2k2}\cdots m_{2kt} \\ \\ m_{zk1}\ m_{zk2}\cdots\ m_{zkt} \end{bmatrix} \quad (\mathrm{z}=1,2,\cdots,\mathrm{g};\ \mathrm{k}=1,2,\cdots,5;\ \mathrm{t}=1,2,\cdots,\mathrm{s}) \quad (1)$$

In formula (1), m_{zkt} represents the value that the Zth groups of the panel on the second level C_k of evaluation indexes of the third level evaluation index x_{kt}. When you evaluate the index of construction environment on project cost. The value of the same index will be differ because of individual diversity. According to the IDC thought of the method, $\min(m_{zkt})$ represents the minimum value of all the groups of the panel on the k th of the second level of evaluation indexes C_k of the t th of the third level evaluation index x_{kt}, that is the common understanding of all the experts group on this evaluation index. $\min(m_{zkt})/q$ represents the identity of all the panel on this evaluation index. Likewise, $\max(m_{zkt})-\min(m_{zkt})$ represents the difference of cognition of all the groups of the panel on this index, $(\max(m_{zkt})-\min(m_{zkt}))/q$ represents variability among all the

panel on this evaluation index, $1-\max(m_{zkt})/q$ represents antagonism of all the panel on this evaluation index[5,6].

According to the above analysis, set pair analysis matrix of the second level of evaluation indexes C_k of the third level evaluation index x_{kt} is constructed and presented in formula (2).

$$\mu_k = [\mu_{k1}\ \mu_{k2}\cdots\mu_{kt}] \quad (k=1,2,\cdots,h;\ t=1,2,\cdots,s) \tag{2}$$

In formula (2), $\mu_{kt} = a_{kt} + b_{kt}i + c_{kt}j$, $a_{kt} = \min(m_{zkt})/q$, $b_{kt} = \max(m_{zkt}) - \min(m_{zkt})/q$, $c_{kt} = 1 - a_{kt} - b_{kt}$. i represents coefficient of variability of all the groups of the panel on this index, j represents coefficient of antagonism of all the panel on this evaluation index. The range of i is $i \in [-1,1]$, it takes different values in different situations. j takes the definite value -1. From this the correlation coefficient of all the third level evaluation index are calculated.

3.2 Determination of the weight of the second class of evaluation index of construction environment on project cost

(1) Construction of judgment matrix. The meaning of judgment matrix division is presented in Tab.2, each two indexes compare and then construct judgment matrix.

Tab.2. The meaning of judgment matrix division

division	meaning
1	Have the same importance
3	The former is a bit more important than the latter
5	The former is obviously more important than the latter
7	The former is particularly more important than the latter
9	The former is extremely more important than the latter
2,4,6,8	The median value of the above-mentioned adjacent value
reciprocal	The degree that the latter is more important than the former

(2) Solution of the weight value. The root mean square method is used as following.

① Calculate the geometric average value of all the elements of each row of the matrix, then make them orthogonal, as formula (3) and formula (4) presented.

$$\overline{w_i} = \sqrt[n]{\prod_{j=1}^{n} a_{ij}} \tag{3}$$

$$w_i = \frac{\overline{w_i}}{\sum_{j=1}^{n} \overline{w_j}} \tag{4}$$

In formula (3) and formula (4), n represents the order of the matrix.

② Calculate the maximum eigenvalue of the matrix, as formula (5) presented.

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(AW)_i}{w_i} \tag{5}$$

③Consistency test of the matrix, as formula (6) an formula (7)presented.

$$C.R. = \frac{C.I.}{R.I.} \tag{6}$$

$$C.I.=\frac{\lambda_{\max}-n}{n-1} \tag{7}$$

In formula (6) and formula (7), $C.I.$ is the index of consistency test, n is the order of the matrix, $R.I.$ is the index of the average random consistency test and its value is presented in Tab.3.

Tab.3. Value of the index of the average random consistency test $R.I.$

order	1	2	3	4	5	6	7	8	9	10
$R.I.$	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

When $C.R.<0.1$, consistency checking result of matrix A is reasonable and efficient, or, matrix A should be adjusted until it satisfies the consistency test.

3.3 Determination of synthesize connection number of the third class of evaluation index of construction environment on project cost

The synthesize connection number u_{kt} is the product of contact number μ_{kt} and the weight of the corresponding second class index w_k. It is presented in formula (8).

$$u_{kt}=\mu_{kt}\cdot w_k (k=1,2,\cdots,5;\ t=1,2,\cdots,s) \tag{8}$$

4. Example

There is a project in Xi'an Yanta District that is contracted by a construction units of secondary release in Shanxi Province. According to the actual situation, 5 groups of panels are selected to evaluate the construction environment on impacting construction cost respectively

4.1 Calculation of connection number of the third class of evaluation index of construction environment on project cost

First, mark for the third level evaluation index. Using set pair analysis to calculate the connection number of the third class of evaluation index. Take the construction organization plan for example, the other four are similar, so final result of calculation are given only.

The evaluation matrix which constructed by the panel on the construction organization plan of the third level evaluation index is presented as M_1.

$$M_1=\begin{bmatrix}8&7&8&6&6\\9&7&6&7&5\\7&8&5&6&6\\9&6&8&5&7\\8&6&6&5&6\end{bmatrix}$$

Calculate the connection number of index x_{1t} as following:

$\mu_{11}=0.7+0.2i+0.1j=0.6+0.2i$

$\mu_{12}=0.6+0.2i+0.2j=0.4+0.2i$,

$\mu_{13}=0.5+0.3i+0.2j=0.3+0.2i$,

$\mu_{14}=0.5+0.2i+0.3j=0.2+0.2i$,

$\mu_{15}=0.5+0.2i+0.3j=0.2+0.2i$. From this the matrix can be got as following:

$\mu_1=[0.6+0.2i,0.4+0.2i,0.3+0.3i,0.2+0.2i,0.2+0.2i]$。

By this method, the connection number of construction period C_2, construction quality C_3, construction safety C_4, construction site management C_5 can be calculated as following:

$\mu_2=[0.4+0.2i,0.5+0.1i,0.5+0.3i,0.2+0.2i,0.6+0.2i]$

$$\mu_3 = [0.2+0.2i, 0.4+0.2i, 0.1+0.2i, 0.1+0.3i]$$
$$\mu_4 = [0.4+0.2i, 0.1+0.3i, 0.3+0.3i]$$
$$\mu_5 = [-0.1+0.3i, 0.2+0.2i, -0.4+0.2i, 0.1+0.3i, -0.2+0.2i]$$

4.2 Calculation of the weight of the second class of evaluation index of construction environment on project cost

According to Tab.2, score the second class of index by the panel, build the judgment matrix and use square root method to calculate eigenvalues and eigenvectors of matrix, and take a disposable test for it, finally obtains the value of the weight of each index, the result is calculated as shown in Tab.4.

Tab.4. Judgment matrix, weight and disposable test

U	U_1	U_2	U_3	U_4	U_5	Product of a row	Extract the 4th root	weight w_i	λ_{max}=5.0681 $C.I.$=0.0170 $R.I.$=5 $C.R.$ =0.0034<0.1, it satisfies the consistency test.
U_1	1	2	3	4	5	120	2.605	0.417	
U_2	1/2	1	2	3	4	12	1.644	0.263	
U_3	1/3	1/2	1	2	3	1	1	0.160	
U_4	1/4	1/3	1/2	1	2	1/12	0.608	0.097	
U_5	1/5	1/4	1/3	1/2	1	1/120	0.384	0.062	
The total							6.241	0.999	

4.3 Calculation of synthesize connection number of the third class of evaluation index of construction environment on project cost

When $i = 0$, that is to say, do not consider the otherness that the panel mark the index when select each index. At last, synthesize connection number can be got. Among them, when $u_{kt} \le 0$ and $u_{kt} = 0$, that is to say, the influence of this index to project cost is very small and can be neglected. The final result is presented in Tab.5.

Tab.5. Synthesize connection number and the ranking

index	weight	contact number	synthesize connection number	ranking	index	weight	contact number	synthesize connection number	ranking
x_{11}	0.417	0.6	0.250	1	x_{32}	0.160	0.4	0.064	10
x_{12}		0.4	0.167	2	x_{33}		0.1	0.016	15
x_{13}		0.3	0.125	6	x_{34}		0.1	0.016	15
x_{14}		0.2	0.083	8	x_{41}	0.097	0.4	0.039	12
x_{15}		0.2	0.083	8	x_{42}		0.1	0.001	19
x_{21}	0.263	0.4	0.105	7	x_{43}		0.3	0.029	14
x_{22}		0.5	0.132	4	x_{51}	0.062	0	0	20
x_{23}		0.5	0.132	4	x_{52}		0.2	0.012	17
x_{24}		0.2	0.053	11	x_{53}		0	0	20
x_{25}		0.6	0.158	3	x_{54}		0.1	0.006	18
x_{31}	0.160	0.2	0.032	13	x_{55}		0	0	20

According to the Tab.6, we can make a conclusion that construction methods and technical

measures, construction machinery and equipment, the occurrence of accident have great impact on project cost, while hydropower and communication arrangement, the position of material and equipment, setting and location of housing and productive house have little impact on it. According to the evaluation result, during the construction, more measures should be taken on the elements that have great impact on project cost and proper measures also should be taken on the elements that have less impact on project cost in order to make the project cost in control.

5. Conclusion

Project cost control is an important element that project management should control. Using set pair analyses is an effective method to evaluate the elements of construction environment on project cost. When applying this method, building a whole and reasonable index system is of great concern. The value of coefficient of variability i will have an impact on the final result, so when using this method, combine the reality, make a proper value for i to ensure the fairness of the evaluation.

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