Research and Demonstration of Bid Selection Decision Model on Construction Engineering

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ABSTRACT
The Principal Component Analysis method (PCA) is introduced into the bid selection decision-making of construction enterprises, the influencing factor index system of bid selection decision-making of construction enterprises is established, the dimensionality of the determined index system is reduced through the dimensionality reduction method of principal component analysis, and the linear relationship between bid selection decision-making and index is determined with the help of computer software calculation. The dimension of 8-dimensional influencing factors is reduced to construct a 2-dimensional linear comprehensive bid selection decision evaluation function. The linear relationship between bid selection decision-making and indicators can ensure the practicability, scientificity and effectiveness of bid selection decision-making in construction enterprises. The practicability and effectiveness of the research results are verified by demonstration.

Keywords: *Bid selection, Principal Component Analysis, Construction engineering.*

1. INTRODUCTION

In the bidding process for the construction enterprises, they need make right bid decision for the right project which they can participate in the bidding, and choose the most suitable engineering to bid. It can achieve the optimal allocation and improve the efficiency of enterprise resources for obtaining the most benefits.

In this paper, the principal component analysis (PCA) is introduced into the construction enterprises bid selection decision-making. Through consulting a large number of references and field visit investigation, the index system for influence factors of construction enterprises bid selection decision was established. Through the PCA method, the dimension of the index system was reduced from 8 to 2. The linear relations between the bidding selection decision and the index was calculated and determined. Make sure that the bid selection decision of construction enterprises is practical, scientific and effective.

2. OVERVIEWS OF RELATED STUDIES

The number of indicators involved in the decision-making is numerous, and these indices have complex correlation, so the analysis is relative difficulty. So we need to simplify the analysis work [1]. Principal Component Analysis method of multi-index can not only reduce the loss in the change of the original information as much as possible, and the original large and complex correlation index has converted to the new comprehensive index of the linear combination. The number of these indicators is smaller and independent or their correlation is small. This method can achieve the effect of reducing the dimension of the evaluation index. At the same time, the new comprehensive index and the original index have linear function relationship, which has more convenient for calculation and research. Xiao Zhi-hong, Yu Jia-lin [2] introduced the application method of Principal Component Analysis, which laid the theoretical foundation for this study.

Based on the problems of principal component analysis method in comprehensive evaluation, Huang Li-wen [3] proposed approximation of ideal point method of principal component analysis and applied the method to the comprehensive evaluation. The results of this paper show that the method can effectively avoid the loss of raw data information loss, and the comprehensive evaluation results are objective and effective. The results have some rationality

In 2014, Sun Zhi-juan [4] analyzed the comprehensive evaluation method of the system and studied the applicability of principal component analysis method in detail in her doctoral dissertation. Based on the study of the diversity and correlation of the single performance index, she compares the applicability of the PCA method in the comprehensive performance analysis and evaluation. Through four expansion methods she improved and optimized the traditional PCA method. The four PCA expansion methods are Kernel Principals Components Analysis (KPCA), Fuzzy Principal Component Analysis (FPCA), global analysis based on PCA-BP Neural Network Model (GPCA) and Relative Principals Components Analysis (RPCA). She introduced four kinds of PCA expansion methods into the comprehensive performance analysis and evaluation, and put forward a specific algorithm for their application methods respectively.

Su Ying-ying [5] combined variables selection and feature extraction methods together in her doctoral dissertation. Using the advantage of Kernel Principals Components Analysis in feature extraction, she proposed nonlinear systems with variable selection method and achieved reliable research results, which provides a basis for the research.

The analysis of nonlinear systems is confronted complex problems with a wide range of data. With the increase of process variables, the computational complexity of the existing low dimensional algorithm is exponential and the generalization ability is poor, which leads to the dimension of the model [6]. There are two methods for processing high-dimensional data [6]. The first method is to select and retain the important variables, which increases the problem of variables selection. But facing the complex nonlinear system decision-making process, there are often characteristics of nonlinear, redundant correlation and lag correlation between the original variables. Therefore, the variable selection problem is very difficult. Another effective way is to replace the original variable with a linear or nonlinear combination of the original variables. Extracting information from the compression, that is, the feature extraction of the components, achieves the dimension reduction effect [7-8]. Construction enterprises are facing the decision problems and this kind of problem is a typical nonlinear system analysis problem with complex and relevant influencing factors. Traditional low dimensional decision method cannot avoid subjectivity. Therefore, this paper attempts to introduce the principal component analysis to the bid selection system.

Wang Shun-hong [9] analyzed several factors of bid selection decision of engineering contractor in his paper. He established 2 quantitative analysis models of the comprehensive value of the project and the possibility of winning the bid. He analyzed three decision-making factors that affect the selection of engineering contractors. They are the possibility of winning the bid, the benefits of the project and the social benefits of the project. He composed the above 3 factors into the comprehensive value of the project and established the impact factor index system of the project selection. But the actual engineering have much complexity, the impact of the indices can not just be from three aspects. On this basis, a relatively comprehensive new selection index system for the bid selection is established in this paper.

The traditional construction market bidding method not only has the subjectivity, but also ignores the correlation between the bid evaluation indices. For this problem, Chen Tao [10] gave a comprehensive bidding evaluation model of the engineering evaluation using principal component analysis (PCA) method. Combining with examples and using SPSS software for data calculation, the final results of the evaluation matched well with the actual situation. This shows that the bidding evaluation model is reasonable and practical. This study gives the idea of the decision-making of bid evaluation, and provides a reference for the selection of the decision-making of the bid selection.

Chen Zhen-fang [11] mainly introduces the method of constructing the index system of bid selection for the construction enterprises. On the basis of summing up his years of experience in project bidding, the research considered the bid selection of engineering projects from 7 aspects. They are: ① project geographical location, ②the goal matching degree between project and the business, ③the intensity of competition in the bidding, ④the fairness of the project supervision, ⑤ the matching degree between project and the company's comprehensive strength, ⑥the familiarity to the project for the enterprise, ⑦the impact for a new investment opportunity. Through comprehensive survey we can confirmed that the index system of the research is still missing. Based on this research, this paper constructs a new index system of bid selection decision for construction enterprises.

3. THE INDEX SYSTEM OF BID SELECTION

The construction projects are closely related to the specific market environment, the economic environment, the social environment and the competition environment. In the bid selection of the subject, the construction enterprise must consider the specific market situation, the construction enterprise itself, the engineering participants and the project itself and so on. These aspects include many factors that exist in the complex relationship. And the nature of the factors is different. There are qualitative factors and quantitative factors. The relationship between the factors is complicated and there is a great sensitivity and uncertainty between them. All these caused a lot of trouble to the bid selection of the construction enterprises [2] [12].

Therefore, for the construction enterprises, the main problem is the factors analysis of bid selection. Only the factors affecting the bid selection of the selection decision can be combined with the specific engineering, the bid selection of the decision-making is reasonable. Through reference materials [9] and field visits investigation, we summarizes a number of engineers engaged in years of working experience in project bidding. It should be from the four aspects to carry on the investigation for construction enterprises in the project bidding decision, including eight main factors. The index system is shown in Table 1.

Table 1. Index System of the factors affecting the bid selection of the construction enterprises

aspects	factors
market situation	number of competitors
	Social benefit
enterprise situation	relative technological strength of the Enterprise
	experience and management skills of the Enterprise
participants	the fund capacity of the owner
	Material supply situation
Project situation	technology difficulty of Construction
	profit amount of the Project

4. PRINCIPAL COMPONENT ANALYSIS MODEL OF BID SELECTION

After the construction of the index system of the bid selection of the construction enterprises, the next important step is to construct the decision model of the construction enterprise. based on a variety of comprehensive analysis decision models, in this study principal component analysis was introduced to the construction enterprises for the bid selection of decision, and the construction enterprises bid selection model is built based on principal component analysis method. The steps are as follows.

(1)8 - dimensional random vector formed by 8 decision - making indices is established. It is $A_j=(a_1,a_2,...,a_8)^T$.

The raw data matrix of the bid scheme is $A=(A_{ij})_{n\times 8}$. A_{ij} is the *jth* influence index of bid selection of the *ith* bidding project which can be chosen.

(2)The raw data matrix is normalized to eliminate the influence of the dimension and the difference of the number of indexes. According to the method of reference [6], we use the method of Formula (1) for the standardization of the raw data matrix.

$$B_{ij}=\frac{A_{ij}-\overline{A_j}}{S_j} \tag{1}$$

Here, B_{ij} is the value of A_{ij} after standardization. $\overline{A_j}$ is the sample average of index. S_j is the standard deviation of sample.

From this, the standard matrix B is obtained.

$$B=\begin{bmatrix} b_{1j} \\ b_{2j} \\ ... \\ b_{nj} \end{bmatrix}=\begin{bmatrix} b_{11} & b_{12} & ... & b_{18} \\ b_{21} & b_{22} ... & & b_{28} \\ ... & ... & ... & ... \\ b_{n1} & b_{n2} ... & & b_{n8} \end{bmatrix} \tag{2}$$

(3)The correlation coefficient matrix $R=(r_{ij})_{8\times 8}$ of the normalized matrix B is calculated. The correlation coefficient of B_i and B_j is r_{ij} .

(4)Calculate all eigenvalues corresponding to the correlation coefficient matrix R. Feature vector sorted by size as follows.

$$\lambda_1>\lambda_2>\lambda_3>\lambda_4>\lambda_5>\lambda_6>\lambda_7>\lambda_8\geq 0$$

Feature vector corresponding to eigenvalues is as follows.

$$t_i=(t_{i1},t_{i2},...,t_{i8}), i=1,2,...,8$$

The principal component analysis equation of the effect index is obtained.

$$C_i=t_{i1}B_1+t_{i2}B_2+...+t_{i8}B_8, i=1,2,...,8. \tag{3}$$

C_i is the principal component analysis equation of i. The characteristic value of C_i is the variance of principal component, and the greater the variance is, the more contribution of the index to the total variation of the main components is. The formula of variance contribution rate is as follows.

$$p_i=\lambda_i \Big/ \sum_{l=1}^{8}\lambda_l \tag{4}$$

p_i reflects the percentage of the impact of the main components of the principal component to the comprehensive raw variable information.

(5)Final principal components. Taking the variance contribution rate p_i of each principal component as the weight, the comprehensive selection decision value function is constructed. D is chosen for the comprehensive selection of bid items, and the formula is calculated as follows.

$$D=\sum_{i=1}^{n}p_iC_i \tag{5}$$

In this paper, the minimum integer m corresponding to the cumulative variance contribution rate

$\sum_{i=1}^{m} p_i \geq 90\%$ of the principal components is determined, and the principal component index of the former m is determined, and the linear comprehensive selection formula of 2 dimensional is calculated as follows.

$$D_m = p_1C_1 + p_2C_2 + ... + p_mC_m \quad (6)$$

5. EXAMPLES

The number of the available bid for a certain enterprise at the same time is 3. According to field survey and comprehensive analysis, the enterprise has given the impact of the various engineering selection index values, as shown in Table 2

Table 2. Index values of raw data for engineering bid selection

Number	Number of competitors	Social benefit(%)	Relative technological strength of the enterprise (%)	Experience and management skills of the enterprise(%)	The fund capacity of the owner (good:9;normal:6;bad:3)	Material supply situation(good:9;normal:6;bad:3)	Technology difficulty of Construction(%)	Profit amount of the project
1	7	100	80	75	3	6	50	500
2	5	50	80	95	6	9	55	300
3	6	70	60	60	6	6	75	700

According to Formula (1), the data are standardized, and the results are shown in Table 3.

Table 3. Standardization index values of raw data for engineering bid selection

Number	Number of competitors	Social benefit(%)	Relative technological strength of the enterprise(%)	Experience and management skills of the enterprise(%)	The fund capacity of the owner (good:9;normal:6;bad:3)	Material supply situation(good:9;normal:6;bad:3)	Technology difficulty of Construction(%)	Profit amount of the project
1	1	1.060	0.577	-0.095	-1.155	-0.577	-0.756	0
2	-1	-0.927	0.577	1.044	0.577	1.155	-0.378	-1.225
3	0	-0.132	-1.155	-0.949	0.577	-0.577	1.134	1.225

Calculate the correlation coefficient of the factors in the matrix of Table 3 with MATLAB. Constitute the 8×8 correlation coefficient matrix of index values normalized data. The results are shown in Table 4.

Table 4. Correlation coefficient matrix of index values normalized data

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
B_1	1.000	0.993	0	-0.570	-0.866	-0.866	-0.189	0.500
B_2	0.993	1.000	0.114	-0.472	-0.918	-0.803	-0.300	0.397
B_3	0	0.114	1.000	0.822	-0.500	0.500	-0.982	-0.866
B_4	-0.570	-0.472	0.822	1.000	0.082	0.904	-0.699	-0.997
B_5	-0.866	-0.918	-0.500	0.082	1.000	0.500	0.655	0
B_6	-0.866	-0.803	0.500	0.904	0.500	1.000	-0.327	-0.866
B_7	-0.189	-0.300	-0.982	-0.699	0.655	-0.327	1.000	0.756
B_8	0.500	0.397	-0.866	-0.997	0	-0.866	0.756	1.000

All eigenvalues and eigenvectors of correlation matrix are calculated by MATLAB. The eigenvalues are sorted according to the order of size. And the eigenvalues C_i are the variance of principal components. According to the formula (4), the variance contribution rate of the main components p_i which is calculated reflects the percentage of the main component of *i* principal component to the comprehensive raw data information. The eigenvalues and the corresponding variance contribution rate are shown in Table 5.

All the feature vector corresponding to the eigenvalues are not shown in this paper. According to $\sum_{i=1}^{m} p_i \geq 90\%$, the first two factors were the main factor of the principal components. Therefore, this example m=2. The principal component factor is determined according to the corresponding indexes of the first two items of the feature values. The feature vector of principal component eigenvalues is shown in Table 6. The evaluation function of the 2 dimensional linear comprehensive selection decision is based on Formula (6).

$$D = 0.57619C_1 + 0.42379C_2 \quad (7)$$

Table 5. Total variance distribution table of standardized data

Principal component	Eigenvalue and variance contribution rate of the correlation coefficient matrix	Principal components

number	λ_i	p_i (%)	$\sum_{i=1}^{n} p_i$ (%)	λ_i	p_i (%)	$\sum_{i=1}^{m} p_i$ (%)
1	4.609	0.576188525	57.619	4.609	57.619	57.619
2	3.390	0.423796724	99.998	3.390	42.379	99.998
3	0.00727	9.0885E-05	100.000			
4	0.000254	3.17535E-05	100.000			
5	0.000164	2.05023E-05	100.000			
6	-0.000167	-2.08773E-05	100.000			
7	-0.00043	-5.37559E-05	100.000			
8	-0.00043	-5.37559E-05	100.000			

Table 6. Principal component extraction matrix of standardized data for the bid selection decision index

Eigenvectors	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
t_1	-0.354	-0.352	0.426	0.252	0.252	0.225	-0.216	0.218
t_2	-0.318	-0.397	-0.561	-0.006	-0.006	-0.193	-0.281	0.085
project1B_i	1	1.060	0.577	-0.095	-1.155	-0.577	-0.756	0
project 2B_i	-1	-0.927	0.577	1.044	0.577	1.155	-0.378	-1.225
project 3B_i	0	-0.132	-1.155	-0.949	0.577	-0.577	1.134	1.225

According to Formula (3), the relationship between the two principal components and the standard data variables is obtained by Table 6.

$$C_1 = -0.354\times B_1 - 0.352\times B_2 + 0.426\times B_3 + 0.252\times B_4 + 0.252\times B_5 + 0.225\times B_6 - 0.216\times B_7 + 0.218\times B_8 \quad (8)$$

$$C_2 = -0.318\times B_1 - 0.397\times B_2 - 0.561\times B_3 - 0.006\times B_4 - 0.006\times B_5 - 0.193\times B_6 - 0.281\times B_7 + 0.085\times B_8 \quad (9)$$

After calculation, the comprehensive evaluation results of bid selection for 3 optional bidding projects which the enterprise is faced are shown as Table 7.

Table 7. Comprehensive evaluation results of bid selection for optional bidding projects

Optional bidding projects	1	2	3
C_1	-0.763	1.409	-0.647
C_2	-0.731	0.132	0.599
D	-0.749	0.868	-0.119
Results numbers	3	1	2

Table 7 shows that No. 2 project is optimum in the 3 optional bid projects. No. 1 is the worse than No. 3. For the enterprise's own interests, the best project for the selection of the bid is No. 2.

6. CONCLUSIONS

In this paper, a decision model of the bid selection for building construction enterprises based on principal component analysis is proposed. The method takes into consideration of the correlation between the various decision indices. The model can effectively avoid the blind subjectivity of the former enterprises participating in bid selection. Through the case analysis, the conclusions are as following. The decision of the principal component analysis is possible and effective. The results of the bid selection are consistent with the actual results, and have enough practical value.

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