Decision Model of Engineering Bid Evaluation and Its Application under Uncertain Information Environment

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Keywords: Engineering bid evaluation; Multi-attribute decision-making; Grey correlation analysis; Interval number

Abstract. In this paper, the decision problem of engineering bid evaluation is studied, and a decision model of engineering bid evaluation is presented based on the method of grey correlation analysis. In this model, all evaluation attribute values are transformed into interval numbers, then a grey correlation degree of interval number sequence is defined to rank all alternative bids. Moreover, an engineering bid evaluation example is given to show the feasibility and effectiveness of this decision model.

Introduction

On January 1, 2000, the bidding law of the People's Republic of China was formally implemented, since then the bidding management of our country's engineering construction project marched into the legalization management track. In the legal system of bidding management, one of the important works is engineering bid assessment. The evaluation process is to select the optimal bid from all tenders. Along with the increasing standardization of bidding management, the evaluation is no longer just is the comparison of the engineering quotation, but to multiple index comprehensive evaluation for all tenders [1-5]. Therefore, how to establish a scientific evaluation method to conduct the bidding assessment work, this is an important subject related to engineering construction management [6-8].

In this paper, we study the decision problem of engineering bid evaluation, and present a decision model of engineering bid evaluation based on the method of grey correlation analysis. We try to provide a new scientific and effective quantitative method for engineering bid evaluation work in practical.

Decision Model of Engineering Bid Evaluation

The problem of engineering bid evaluation can be described as follows.

A department of construction management will organize a project bidding, and there are m bidders submit bids, which denoted as $x_1, x_2, ..., x_m$. Six evaluation attributes are given to evaluate the m bids, i.e., G_1 bid price (ten thousand yuan), G_2 delivery time (months), G_3 the main needed materials (ten thousand yuan), G_4 the construction plan, G_5 the quality performance and G_6 corporate reputation. The weight w_i of attribute G_i satisfies the conditions $w_j \in [c_j, d_j]$, where $0 \le c_j \le d_j \le 1$, $j = 1, 2, ..., n$, and $w_1 + w_2 + ... + w_n = 1$. The value of attribute G_j for bid x_i is denoted as a_{ij}, and the original decision matrix is denoted as $A = (a_{ij})_{m\times 6}$. From the information of matrix A, our goal is to select an optimal bidder among m bidders to do this engineering project.

Now a decision model of engineering bid evaluation is presented based on the method of grey correlation analysis to solve the decision problem of engineering bid evaluation. The decision steps are given as follows.

(1) Transform all evaluation attribute values into interval numbers.

In the practical decision making, there are three types data for the above six evaluation attributes given by the decision makers, i.e., the evaluation values of G_1 and G_3 are given in the form of precision numbers, the evaluation values of G_2 are given in the form of interval numbers, and the evaluation values of G_4, G_5 and G_6 are generally in the form of linguistic fuzzy numbers such as "very good, good, common, poor, very poor" or "very high, high, common, low, very low".

For a precision number a_{ij}, the corresponding interval number is $[a_{ij}, a_{ij}]$.

For the linguistic fuzzy numbers such as "very good, good, common, poor, very poor" or "very high, high, common, low, very low", the method of transforming them into interval numbers are given as follows.

very good=[80, 100], good=[60, 80], common=[40, 60], poor=[20, 40], very poor=[0, 20];

very high=[80, 100], high=[60, 80], common=[40, 60], low=[20, 40], very low=[0, 20].

Based on the above transformed method, suppose that the value of a_{ij} attribute G_j on x_i is transformed into interval number $\left[a_{ij}^-, a_{ij}^+\right]$, j=1, 2, …, 6, then the original matrix A becomes

$$B=\begin{bmatrix} \left[a_{11}^-,a_{11}^+\right] & \left[a_{12}^-,a_{12}^+\right] & \cdots & \left[a_{16}^-,a_{16}^+\right] \\ \left[a_{21}^-,a_{21}^+\right] & \left[a_{22}^-,a_{22}^+\right] & \cdots & \left[a_{26}^-,a_{26}^+\right] \\ \cdots & \cdots & & \cdots \\ \left[a_{m1}^-,a_{m1}^+\right] & \left[a_{m2}^-,a_{m2}^+\right] & \cdots & \left[a_{m6}^-,a_{m6}^+\right] \end{bmatrix}.$$

(2) Transform reverse attribute into positive attribute.

The positive attribute means that the greater the value is, the better the attribute is, and the positive attribute means that the smaller the value is, the better the attribute is. Due to the attributes G_1 bid price, G_2 delivery time and G_3 the main needed materials are all positive attributes, we can use the following method to transform these reverse attributes into positive attributes, i.e.,

$$\left[b_{ij}^-, b_{ij}^+\right]=\left[-a_{ij}^-, -a_{ij}^+\right], i=1,2,...,m,\ j=1, 2, 3,$$

and the transformed matrix is denoted as $C=(\left[b_{ij}^-, b_{ij}^+\right])_{m\times 6}$.

(3) Standardize the transformed matrix C.

The standardized matrix is denoted as $R=\left[r_{ij}^-, r_{ij}^+\right]_{m\times 6}$, where

$$\left[r_{ij}^-, r_{ij}^+\right]=\frac{\left[b_{ij}^-, b_{ij}^+\right]}{\left\|A_j\right\|},\quad i=1,2,...,m,\ j=1,2,...,6.$$

where $\left\|A_j\right\|$ is a bound norm expressed by the following formula.

$$\left\|A_j\right\|=\max(\max(\left|a_{1j}^-\right|,\left|a_{1j}^+\right|),\max(\left|a_{2j}^-\right|,\left|a_{2j}^+\right|),\cdots,\max(\left|a_{mj}^-\right|,\left|a_{mj}^+\right|))\quad j=1,2,\ldots,6$$

(4) Weight the standardized matrix R.

The weighted matrix is denoted as $E=\left[e_{ij}^-, e_{ij}^+\right]_{m\times 6}$, where

$$\left[e_{ij}^-, e_{ij}^+\right]=\left[w_j, w_j\right]\cdot\left[r_{ij}^-, r_{ij}^+\right], i=1,2,...,m,\ j=1,2,...,6.$$

(5) Determine the reference sequence

We set

$$u_0^-(j)=\max_{1\le i\le N} e_{ij}^-,\ \ j=1,2,...,n,$$

$$u_0^+(j)=\max_{1\le i\le N} e_{ij}^+,\ \ j=1,2,...,n,$$

then the reference sequence is defined as

$$U_0=\left(\left[u_0^-(1),u_0^+(1)\right],\left[u_0^-(2),u_0^+(2)\right],...,\left[u_0^-(n),u_0^+(n)\right]\right).$$

(6) Calculate the grey correlation degree between each bid sequence and the reference sequence.

We set

$$\Delta_i(j)=\left\|\left[u_0^-(j),u_0^+(j)\right]-\left[c_{ij}^-, c_{ij}^+\right]\right\|, \tag{1}$$

$$\xi_i(j)=\frac{\min\limits_i\min\limits_k\Delta_i(j)+\rho\max\limits_i\max\limits_k\Delta_i(j)}{\Delta_i(j)+\rho\max\limits_i\max\limits_k\Delta_i(j)} \quad (2)$$

where $\zeta_i(j)$ is the grey correlation coefficient, and $\rho = 0.5$, is the discrimination. Based on the values of $\zeta_i(j)$, we can calculate the grey correlation degree r_i between each bid sequence x_i and the reference sequence U_0, the computing formula is as follows.

$$r_i=\frac{1}{n}.\sum_{j=1}^{6}w_j\xi_i(j), \qquad i=1,2,...,m. \quad (3)$$

The greater the value of r_i is, the better the bid x_i.

Decision Example of Engineering Bid Evaluation

Suppose that a department of construction management will organize a project bidding, and there are four bidders submit bids, which denoted as $x_1, x_2, ..., x_4$. Six evaluation attributes are given to evaluate the m bids, i.e., G_1 bid price (ten thousand yuan), G_2 delivery time (months), G_3 the main needed materials (ten thousand yuan), G_4 the construction plan, G_5 the quality performance and G_6 corporate reputation. The weight w_i of attribute G_i are given in Table 1. The value a_{ij} of attribute G_j on bid x_i is listed in Table 1. Now our task is to select an optimal bidder among four bidders to do this engineering project.

Table 1. The bid information

	G_1	G_2	G_3	G_4	G_5	G_6
x_1	480	[12, 14]	192	Very good	Good	High
x_2	490	[14, 16]	196	Good	Common	Common
x_3	501	[13, 15]	204	Good	Good	Very high
x_4	475	[16, 18]	190	Common	Very good	Common
Weight	0.3	0.1	0.1	0.2	0.1	0.2

From the data in Table 1, the decision process based on the method given in Section 2 is given as follows.

(1) Construct the interval decision matrix B.

From Table 1, we can see that there three types data, i.e., the evaluation values of G_1 and G_3 are all precision numbers, the evaluation values of G_1 are interval numbers, and the evaluation values of G_4, G_5 and G_6 are all linguistic fuzzy numbers such as "very good, good, common, poor, very poor" or "very high, high, common, low, very low". By using the transformation method given by Section 2.2, we can get the interval decision matrix B as follows.

$$B=\begin{bmatrix}[480,480] & [12,14] & [192,192] & [80,100] & [60,80] & [60,80]\\ [490,490] & [14,16] & [196,196] & [60,80] & [40,60] & [40,60]\\ [501,501] & [13,15] & [204,204] & [60,80] & [60,80] & [80,100]\\ [475,475] & [16,18] & [190,190] & [40,60] & [80,100] & [40,60]\end{bmatrix}.$$

(2) Standardize the transformed matrix B.

We set

$\|A_1\|=[501,501]$, $\|A_2\|=[16,18]$, $\|A_3\|=[204,204]$,

$\|A_4\|=[80,100]$, $\|A_5\|=[80,100]$, $\|A_6\|=[80,100]$,

then we obtain the standardized matrix as

$$R=\begin{bmatrix}[0.9581,0.9581] & [0.6667,0.7778] & [0.9412,0.9412] & [0.8000,1.0000] & [0.6000,0.8000] & [0.6000,0.8000]\\ [0.9780,0.9780] & [0.7778,0.8889] & [0.9608,0.9608] & [0.6000,0.8000] & [0.4000,0.6000] & [0.4000,0.6000]\\ [1.0000,1.0000] & [0.7222,0.8333] & [1.0000,1.0000] & [0.6000,0.8000] & [0.6000,0.8000] & [0.8000,1.0000]\\ [0.9481,0.9481] & [0.8889,1.0000] & [0.9314,0.9314] & [0.4000,0.6000] & [0.8000,1.0000] & [0.4000,0.6000]\end{bmatrix},$$

$W=\big[[0.3,0.3][0.1,0.1][0.1,0.1][0.2,0.2][0.1,0.1][0.2,0.2]\big]$.

(3) Weight the standardized matrix *R*.

By using the weighted method given by Section 2.2, we can get the weighted matrix *E* as

$$E=\begin{bmatrix}[0.2874,0.2874][0.0667,0.0778][0.0941,0.0941][0.1600,0.2000][0.0600,0.0800][0.1200,0.1600]\\ [0.2934,0.2934][0.0778,0.0889][0.0961,0.0961][0.1200,0.1600][0.0400,0.0600][0.0800,0.1200]\\ [0.3000,0.3000][0.0722,0.0833][0.1000,0.1000][0.1200,0.1600][0.0600,0.0800][0.1600,0.2000]\\ [0.2844,0.2844][0.0889,0.1000][0.0931,0.0931][0.0800,0.1200][0.0800,0.1000][0.0800,0.1200]\end{bmatrix}$$

(4) Determine the reference sequence

For matrix *E*, the reference sequence U_0 is

$U_0=\big([0.3,0.3],[0.0889,0.1],[0.1,0.1],[0.16,0.2],[0.08,0.1],[0.16,0.2]\big)$.

(5) Calculate the grey correlation degree between each bid sequence and the reference sequence.

By using the formulas (1), (2) and (3), we get the grey correlation coefficient and grey correlation degree as follows.

$\xi_1=(0.7608,0.6429,0.8718,1.0000,0.6667,0.5000)$,

$\xi_2=(0.8586,0.7826,0.9107,0.5000,0.5000,0.3333)$,

$\xi_3=(1.0000,0.7059,1.0000,0.5000,0.6667,1.0000)$,

$\xi_4=(0.7198,1.0000,0.8536,0.3333,1.0000,0.3333)$,

$r_1=0.740366667$,

$r_2=0.647533333$,

$r_3=0.8121$,

$r_4=0.706666667$.

According to the values of grey correlation degree r_i, we can get the rank order of four bids as follows.

$x_3\succ x_1\succ x_4\succ x_2$.

Thus, the winner of the bid is x_3.

Conclusion

In this paper, we study the decision problem of engineering bid evaluation, and present a decision model of engineering bid evaluation based on the method of grey correlation analysis. This decision model can meet the need of comprehensive assessment of the reasonable construction units for the related management department of engineering construction. It can objectively and accurately reflect the strength of the bidding units, and have certain comparability and unity, and it also can avoid the subjective randomness, thus provide a scientific and effective quantitative method for the engineering bid evaluation work.

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