Chapter 63
The Application of Rough Set in Bid Evaluation Method

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Abstract Whether the bid evaluation method is scientific, reasonable and justice, can directly affect the bidding and influence the results of the competition. The bid evaluation method based on Rough Set was put forward. The evaluation indexes were determined according to the specific requirements of the project and the goals of the employers, the indexes were reduced adopting the attribute reduction based on the information quantity, the significance of indexes was used to determine the index weights, and the comprehensive evaluation values of the contractors were calculated. The case of hospital project was studied and analyzed, it shows that this method reduces the subjectivity of experts to a great extent and provides objective and quantitative decision basis for decision makers. The ideal contractor is chosen and the advantages of the integration of design, purchase and construction are expressed.

Keywords Attribute reduction • Bid evaluation method • Information quantity • Significance

Introduction

In recent years, the general contracting (EPC) model develops rapidly because of its own disadvantages in international construction market. In China, the EPC model has been applied gradually in practice and supported by our related law in

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engineering construction. EPC is defined as the contractors are entrusted by employers to implement the total proceeding and several stages including survey, design, purchase, construction and test run. In this paper, the EPC is the integration of design, purchase and construction (Shui-bo Zhang et al. 2005). There are lots of comprehensive bid evaluation methods at present, Li-ming Liang (Li-ming Liang et al. 2006; Guo-xiang Hu et al. 2003) used AHP to bidding and built the bidding model; De-yu Huang (De-yu Huang and Xin Chen 2005) described qualitative norms and their important degree using fuzzy number according to the characteristic of group decision making and the synthetically sequencing numerical values were calculated; Chen Tao (2005) established the comprehensive evaluation model of bidding the construction adopting principal components analysis.

The subjective methods such as AHP, fuzzy evaluation has lots of human factors affecting the index weights and lack the objectivity, the objective methods has limitations, for example, the principal components analysis cannot explain the real meaning (Ning Mu and Kai-chao Yu 2010). The method of Rough set was used to make up for the lack of the previous study and study the bid evaluation. This paper proceeded as follows: first, the evaluation indexes were determined according to the specific requirements of the project and the goals of the employers, the Attribute Reduction algorithm based on information quantity was used to reduce the evaluation indexes and optimize index system and the reduced attribute were acquired; then the significance of indexes was used to determine the index weights; lastly, the comprehensive evaluation values of the contractors were calculated. This method solves the problems of subjectivity and one-sidedness existing in the traditional method, decreases the amount of computation on the comprehensive evaluation, reduces the subjectivity of experts to a great extent and provides objective and quantitative decision basis for decision makers.

The Theoretical Knowledge of Rough Set

Rough Set was put forward by Zdzislaw Pawlak in the early 1980s to analyze the data tables. The initial data were acquired from measurements or from experts (Jan Komorowski 1998). The rough set has lots advantages in processing the initial data as follows:

1. Synthesis of efficient algorithms for digging the potential information in data;
2. Reduction of data to get a minimal model;
3. Calculation of the significance of data;
4. Processing of both qualitative and quantitative parameters;
5. Reduction of the subjectivity of experts to a great extent;
6. Support of the objective and quantitative decision basis for decision makers (Duntsch 1997).

Information System

Definition 1. An information system $S = (U, A, V, f)$, U is the finite set of objects and defined as the domain; $V = \bigcup_{a \in A} V_a$, V_a is the domain of the attribute a; $f : U \times A \to V$ is an information function providing a value for the attribute of every object, $a \in A, x \in U, f(x, a) \in V_a$.

Equivalence Relation

Each attribute subset $P \subseteq A$ determines an equivalence relation IND(P), the information system $S = (U, A, V, f)$ is defined as knowledge A.

Definition 2. If $(x, y) \in IND(P)$ is equivalent, x is equivalent to y. The equivalence relation IND(P) forms a equivalence partitioning in U, $U/IND(P) = \{X_1, X_2, \ldots X_n, \}$ is the expression form.

The Core and Reduction of the Attribute

Definition 3. An information system $S = (U, A, V, f), a \in A$, if IND(A−{a}) = IND (A), the attribute a is unnecessary in A, or a is necessary in A.

Definition 4. An information system $S = (U, A, V, f)$, the set consisting of all the necessary attributes is the core Core(A) of attribute set A.

Definition 5. An information system $S = (U, A, V, f)$, if $P \subseteq A$:

1. IND(P) = IND(A);
2. P is independent.;
   P is a reduction of A.

The Information Quantity and the Significance of Knowledge

Definition 6. An information system $S = (U, A, V, f)$, $P \subseteq A$, $U/IND(P) = \{X_1, X_2, \ldots, X_n\}$. The definition of information quantity of knowledge P is defined as:

$$I(P) = \sum_{i=1}^{n} \frac{|X_i|}{|U|}\left[1 - \frac{|X_i|}{|U|}\right] = 1 - \frac{1}{|U|^2} \sum_{i=1}^{n} |X_i|^2. \quad (63.1)$$

$|X|$ is the radix of the set X, $\frac{|X_i|}{U}$ is the probability of the equivalence class $|X_i|$ in U.

Definition 7. An information system $S = (U, A, V, f)$, the importance of the attribute a in A is :

$$sig_{A-\{a\}} = I(A) - I(A - \{a\}). \quad (63.2)$$

Definition 8. An information system $S = (U, A, V, f)$, $C \subseteq A$, the importance of arbitrary attribute $a \in A - C$ for attribute set C is defined as follow (Xue-min Zheng 2010; Yi-tan and Lai-sheng 2006):

$$sigC(a) = sig_{C\cup\{a\}-\{a\}} = I(C \cup \{a\}) - I(C). \quad (63.3)$$

The Bid Evaluation Model Based on Rough Set

The Establishment of the Bid Evaluation Indexes

The bid evaluation is a complex and very important work. For a specific project, the reasonable evaluation methods should be taken and the evaluation indexes are determined according to the specific requirements of the project and the goals of the employers. The bid evaluation projects were shown respectively from the commercial affairs, technology and management.

1. Commercial Indexes
   The commercial indexes are to control the employer's engineering cost. Not only the engineering bid but also operation costs in the whole cycle are considered due to the different design options. The higher operation costs, the lower score of the indexes. In addition, the rationality of the bid should also be considered, for example, the whole bid can be decomposed as design, purchase, and construction.
2. Technical Indexes
   The design options are raised according to employer's requirements in bidding document of EPC. The employers take some factors into account to judge the design options, such as the integrity and innovativeness of the design, the advancement of the permanent facilities and equipment, the overall construction etc.
3. Management Indexes
   Under the practicable design options, whether the engineering project can be completed on time, having high quality, safely and environmentally depend on the management level of the contractors. The management level is shown in planned capacity, organizational capability and control ability etc.

In order to make the bid evaluation more practical and manipulable, a set of complete, scientific and comprehensive bid evaluation system must to be built. In this paper, all just are used for explaining this model, nine indexes are chosen including engineering bid, operation cost in the whole cycle, the rationality of the

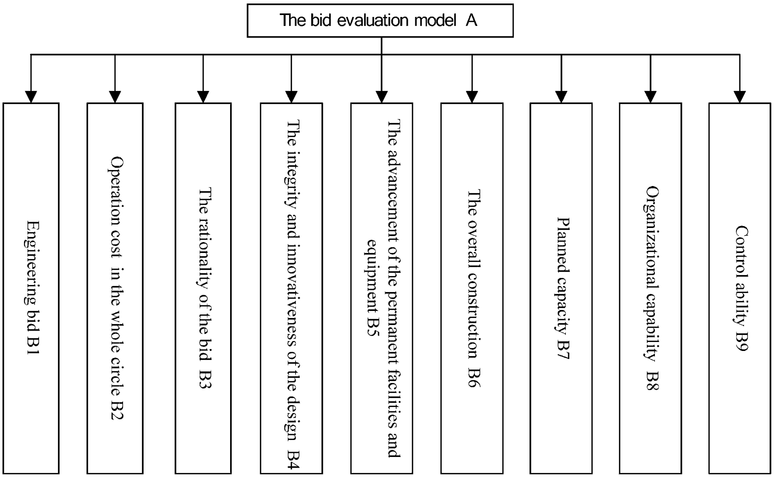

Fig. 63.1 The bid evaluation model

bid, the integrity and innovativeness of the design, the advancement of the permanent facilities and equipment, the overall construction, planned capacity, organizational capability and control ability. The bid evaluation model is as follow in Fig. 63.1:

The Reduction of Evaluation Indexes

The main steps of the algorithm are as follows:

1. The formula (63.1) is used to calculate the information quantity $I(A)$;
2. Firstly, $Core(A) = \emptyset$, the formula (63.2) is adopted to calculate the significance of every $a_i \in A$. If $sig_{A-\{a_i\}}(a_i)$ is not 0, $Core = Core \cup \{a_i\}$, the core of index set A is got and then calculate $I(Core)$. If $I(Core) = I(A)$, the algorithm ends (this $Core$ is the minimum approximate reduction, or go to (3);
3. $C = Core$, the index set $A - C$ can be calculated repeatedly:
   The formula (63.3) can be used to calculate the significance $sig_C(a_i)$ of every attribution $a_i \in A - C$;
   The maximum $sig_C(a_i)$ is got, then $C := C \cup \{a_i\}$;
   If $I(C) = I(A)$, the algorithm ends (C is one of the minimum approximate reduction of A); or go to (1).

The Case Study

To verify the effectiveness of this model based on Rough Set, four contractors were chose to be studied.

Table 63.1 The initial information table

	B1	B2	B3	B4	B5	B6	B7	B8	B9
U1	6	6	7	8	8	8	6	7	7
U2	8	7	7	6	9	8	6	7	6
U3	8	6	6	9	8	9	7	7	7
U4	7	8	6	8	5	7	6	5	7

U1, U2, U3, U4 stood for four contractors

Table 63.2 The discrete information table

	B1	B2	B3	B4	B5	B6	B7	B8	B9
U1	2	2	2	1	1	1	2	2	2
U2	1	2	2	2	1	1	2	2	2
U3	1	2	2	1	1	1	2	2	2
U4	2	1	2	1	3	2	2	3	2

Data Collection

The committee of bid evaluation consists of the representative familiar with the relative business and the experts about technique and economy. Likert 10-level measuring was used to divide the score into 11 levels, 10 meant to be very satisfied with the index, 0 meant to be very dissatisfied with the index (Paddock et al. 2000). Firstly, the initial score were rated by the committee as follows in Table 63.1. Then the initial information sheet were discretized, in the discretization in this paper, 1 stood for 8–9, 2 stood for 6–7, 3 stood for 4–5, therefore, the discrete information table was as shown in Table 63.2.

The Reduction of the Indexes

1. According to the information system, the equivalence relation U/IND(A) = {U1, U2, U3, U4}, I(A) = 12/16;
2. For index set A−{a1}, the equivalence relation U/IND(A−{a1}) = {U1, {U2, U3}, U4}. According to the formula (63.2), $sig_{A-\{a1\}} = I(A) - I(A - \{a1\})$ $= 2/16$, in the same way, $sig_{A-\{a2\}}(a2) = sig_{A-\{a2\}}(a3) = sig_{A-\{a2\}}(a5) = sig_{A-\{a2\}}(a6) = sig_{A-\{a2\}}(a7) = sig_{A-\{a2\}}(a8) = sig_{A-\{a2\}}(a9) = 0$, $sig_{A-\{a4\}} = 2/16$. So Core(A) = {a1, a4}, I(Core) = 10/16 ≠ I(A).
3. C = Core, the index set A–C can be calculated repeatedly:
   According to the formula (63.3), the significance can be calculated: $sig_C(a2) = sig_C(a5) = sig_C(a6) = sig_C(a8) = 2/16$, $sig_C(a3) = sig_C(a7) = sig_C(a9) = 0$.
   I(a1, a2, a4)= I(a1, a4, a5)= I(a1, a4, a6)= I(a1, a4, a8)= I(A).
   Now {a1, a4, a6} was chosen as the reduced index set.

The Calculation of the Index Weights

The weights of three reduced indexes were calculated and the steps were as follows:

1. The division of the domain U based on the equivalence relation C:U/IND (C) = {U1,U2,U3,U4}; I(C) = 12/16 according to the formula (63.1);
2. The significance of the attribute: $sig_{C-\{a1\}}(a1) = 6/16$, $sig_{C-\{a4\}}(a4) = sig_{C-\{a4\}}(a6) = 2/16$;
3. The weights were normalized, $W_1 = \frac{sig_{C-\{a1\}}(a1)}{sig_{C-\{a1\}}(a1)+sig_{C-\{a4\}}(a4)+sig_{C-\{a6\}}(a6)} = \frac{3}{5}$, $W_{a4} = W_{a6} = \frac{1}{5}$.

The Comprehensive Evaluation Values

The evaluation values of every object were calculated using linear weighted model: U1 = 6.8, U2 = 7.6, U3 = 8.4, U4 = 7.2.

Determining the weights was one of the key issues of bidding, it can be seen from the weights that engineering bid was the most important factor, followed by the integrity and innovativeness of the design and the overall construction. From the results of evaluation values, the highest score was U3, the employers can chose the best contractor from this result.

Conclusion

Because the factors affecting the bidding are very large and the significance of each factor has big difference, the comprehensive and data-driven completely bid evaluation method was put forward based on Rough set. This model was applied into hospital project and proven objectivity and practicality overcoming the problems of the traditional methods, such as subjectivity and partiality. Adopting the attribute reduction shown the comprehensiveness of bid evaluation and simplify the arithmetical complexity, the objectivity of bid evaluation was emphasized and the subjective experience was used in calculating the weights of each factor. All can help finishing the bidding equally, fairly and scientifically and choose the ideal contractor who has high quality, short duration and reasonable cost.

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