Study on QFD Method in the Selection of Engineering Material Suppliers

Zhen FENG[1,a,*], Yue JIN[1,b], Cheng WANG[1]

[1]School of Management Science and Engineering, Shanxi University of Finance and Economics, Taiyuan, China

[a]fengzhen4@126.com, [b]1546304906@qq.com

*Corresponding author

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Abstract. In order to reduce the emotional factors in the selection of engineering material suppliers, QFD is applied to propose the quantitative method of selection of engineering material suppliers, and transform requirements of engineering materials into engineering and service characteristics that can be measured accurately. Through experts' evaluation, the relative weight of each requirement, the correlation between engineering and service characteristics are determined. The weight of each engineering and service characteristic is calculated accordingly to obtain the quality of house selected by the supplier. The supplier's performance in engineering and service characteristics is then scored through the bidding group's review. Finally, the comprehensive score of the supplier is calculated by using the weight of engineering and service characteristics and the performance score of the supplier in engineering and service characteristics, so as to obtain the ranking of the supplier. An example is given to verify the effectiveness of the proposed method and the selection strategy of engineering material supplier is also analyzed.

Introduction

China's economy will enter the stage of high-quality development from high-speed development, and requirements on engineering quality are gradually improved. Engineering units are more and more committed to the quality control of raw material procurement, which makes the material department to have more scientific basis for selection when bidding for procurement. At present, factors considered in the bidding and procurement of general engineering units include factory price, haul distance, supplier qualification and previous cooperation experience, among which the former cooperation experience accounts for a large proportion, and the effect of quantitative index is weakened.

In the previous analysis of supplier selection, fuzzy comprehensive evaluation method [1], AHP [2] and Kano [3] were mainly used. In recent years, with the deeper study of Quality Function Deployment (QFD), it's also used in supplier selection. TS Nguyen (2016) developed a hybrid model for non-homogeneous group decision making in the supplier selection process based on QFD [4]. M Liu (2017) innovated QFD based on 2-tuple linguistic model to evaluate tourism suppliers [5]. It can be seen that only engineering characteristics are considered but service characteristics are not.

Based on this, this paper will use the QFD method to transform the engineering unit's demands into quantifiable engineering characteristics and service characteristics, and then calculates the comprehensive scores of suppliers as the reasonable selection basis. We will take procurement of an engineering unit called HRB400 Φ 20 as a case to determine the applicability of the method, and analyze the selection strategy of the engineering unit.

Basic Structure of Quality House

The QFD method can meet or even exceed the needs of customers by establishing House of Quality (HoQ) and various improvement methods and approaches. The key to the QFD method is to establish HoQ, and figure 1 is the basic composition of HoQ.

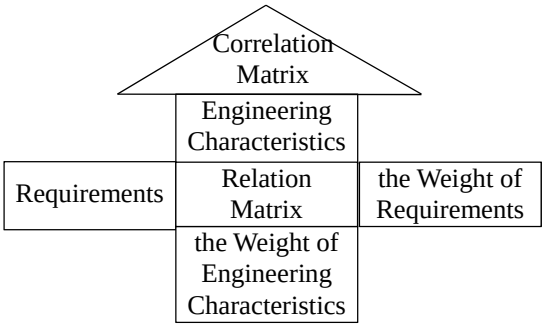


Fig. 1, the Basic Structure of HoQ

In Figure 1, the requirement CR is measured by the weight of each requirement. The degree of correlation between engineering characteristic EC is expressed in correlation matrix. Relation matrix CR-EC refers to the relationship between CR and EC. These three indexes are usually determined by expert scoring. The weight of EC is used to measure the importance of various EC under the specific needs of customers, which is obtained by the comprehensive calculation of the first three indexes. According to EC, the resources between EC can be reasonably allocated to maximize customer satisfaction.

Method Derivation

Parameter Definition

The mathematical symbols used in this paper are shown in Table 1:

Table 1, Parameter definition

Mathematical Symbols	the Meaning	Mathematical Symbols	the Meaning
A_p	the p supplier	R_1'	standardization of R_1
CR_i	the i customer requirement	R_2	Correlation between CR_i and SC_j
W_i	the weight of CR_i	R_2'	standardization of R_2
EC_j	engineering characteristics	r_1	correlations in EC_j
K_j	the weight of engineering characteristics	r_2	correlations in SC_j
SC_j	service characteristics	Z_{p1}	the weighted score of the P supplier on EC_j
L_j	the weight of service characteristics	Z_{p2}	the weighted score of the P supplier on SC_j
R_1	Correlation between CR_i and EC_j		

Model Formulas

Some common basic formulas need to be used in the derivation of supplier selection method. The details are as follows.

Standardize R1 and R2:

$$R_1'=\frac{\sum R_1 \cdot r_1}{\sum\sum R_1 \cdot r_1} \quad (1)$$

$$R_2'=\frac{\sum R_2 \cdot r_2}{\sum\sum R_2 \cdot r_2} \quad (2)$$

The weight of EC is determined by the weight of CR and the correlation of standardized CR-EC:

$$K_j=\sum W_i \cdot R_1' \quad (3)$$

The weight of SC is determined by the weight of CR and the correlation of standardized CR-EC:

$$L_j=\sum W_i \cdot R_2' \quad (4)$$

The weighted score of the P supplier is determined by the P supplier's score on EC and the weight of EC:

$$Z_{p1}=\sum X_{p1} \cdot K_j \quad (5)$$

The weighted score of the P supplier on SC is determined by the P supplier's score on SC and the weight of SC:

$$Z_{p2}=\sum X_{p2} \cdot L_j \quad (6)$$

The formula of the P supplier's total score is:

$$Z_p=Z_{p1}+Z_{p2} \quad (7)$$

Model Building

The process of establishing the supplier evaluation model is as follows.

1. Determine the *CR* set and its relative weight. By discussing the requirements in terms of cost, quality, service and cooperation risk, the bidding group determinesCR_i. Then, the importance is evaluated by experts in the bidding group, and the weight W_i of CR_i is obtained.

2. Determine *EC*, *SC* set and correlation between *EC* and *SC*. All *EC* and *SC* related to *CR* are determined through discussion among experts in the bidding group. Since there may be interaction between *EC* and *SC*, the self-correlation strength matrix is obtained by expert evaluation.

3. Determine *CR-EC* and *CR-SC* relation matrix. As (2), the evaluation shall be conducted directly after discussion by the experts of the bidding group. Standardize them based on (1) and (2).

4. Calculate the weight of *EC* and *SC* according to (3) (4);

5. The performance of each supplier on *EC* and *SC* will be scored after the evaluation by the bidding group experts.

6. The total score of each supplier is obtained by using (5), (6), (7). Then the suppliers are ranked according to the score. The optimal selection strategy of the suppliers is finally obtained.

Case and Analysis

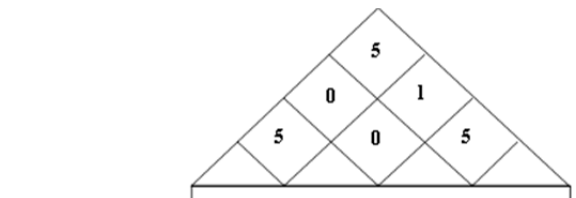
An engineering unit wants to bid for screw steel required for construction. With HRB400Φ20's purchasing process, for example, through preliminary screening, there are 4 suppliers have qualifications. Four suppliers' information is shown in Table 2:

Table 2, Supplier information

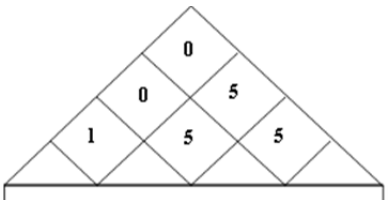
Supplier	Technical Features EC			
	Diameter Deviation (±0.5mm)	Spacing Deviation (±0.8mm)	Length Deviation (-50mm)	Theoretical Deviation (-5%kg)
A_1	±0.27	±0.51	-35	-3.20%
A_2	±0.33	±0.22	-27	-0.80%
A_3	±0.08	±0.37	-37	-2.70%
A_4	±0.17	±0.45	-32	-1.20%
Supplier	Service Features SC			
	Ex-Factory Price (Yuan/ton)	Load Distance (km)	Lead Time (day)	Number of Warehouses
A_1	3650	200	7	2
A_2	3720	30	3	2
A_3	3713	97	6	5
A_4	3650	18	5	1

In Table 2, the four suppliers are A_1, A_2, A_3 and A_4.The biding group discussed that the technical features involved in the purchase of HRB400Φ20 were as follows: EC_1 is the diameter deviation of single rebar.EC_2 is the spacing deviation of rebar. EC_3 is the length deviation of single rebar. EC_4 is the deviation of actual weight and theoretical weight of single rebar. The service features involved include: SC_1 is the ex-factory price per ton.SC_2 the distance from the warehouse to the delivery place for the supplier.SC_3 is the lead time of the purchaser's order. SC_4 is the number of warehouses owned by the supplier.

According to the evaluation of experts, QoH of this problem is shown in Figure 3 and Figure 4:



CR_i	W_i	EC_1	EC_2	EC_3	EC_4
CR_1	0.85	5	3	5	5
CR_2	0.36	1	1	3	5
CR_3	0.76	5	1	3	5



CR_i	W_i	EC_1	EC_2	EC_3	EC_4
CR_1	0.85	1	1	1	1
CR_2	0.36	1	5	5	1
CR_3	0.76	5	3	1	5

Fig. 3, QoH based on technical characteristics Fig. 4, QoH based on service characteristics

In Figure 3 and Figure 4, the HRB400 Φ 20's *CR* is determined by bidding group of expert evaluation.CR_1 is the process flow.CR_2 is the influence of construction period.CR_3 is cost control.

The weight of *CR* in Figure 3 and 4, the correlation degree between *CR* and *EC* and correlation degree between *EC* in Figure 3, the correlation degree between *CR* and *SC* and the degree of correlation between *SC* in Figure 4 are all determined by the experts of the bidding group according to the bidding document and the project unit construction quality manual.

According to the data in Figure 3, the standardization R_1' of *CR-EC* relational matrix can be achieved by formula 1, as shown in Table 3:

Table 3, Standardization R_1' of CR-EC relational matrix

Feature	EC_1	EC_2	EC_3	EC_4
CR_1	0.27	0.20	0.18	0.35
CR_2	0.32	0.11	0.29	0.27
CR_3	0.25	0.22	0.20	0.33

According to the data in Figure 3, the standardization R_2' of CR-SC relational matrix can be achieved by formula 2, as shown in Table 4:

Table 4, Standardization R_2' of CR-SC relational matrix

	SC_1	SC_2	SC_3	SC_4
CR_1	0.06	0.33	0.31	0.31
CR_2	0.05	0.28	0.27	0.40
CR_3	0.07	0.34	0.37	0.22

On this basis, the weight K_j of *EC* is calculated by using the formula 3, as shown in Table 5:

Table 5, The weight K_j of EC

K_1	K_2	K_3	K_4
0.54	0.38	0.41	0.64

Calculate the weight L_j of SC according to the formula 4, as shown in Table 5.

Table 6, The Weight L_j of EC

L_1	L_2	L_3	L_4
0.12	0.64	0.64	0.57

The specification of EC1 is ±0.5mm and the scoring criteria is as follows:
When $EC_1 \in [(-0.1,0) \cup (0,0.1)]$,the score is 9 points.
When $EC_1 \in [(-0.2,-0.1) \cup (0.1,0.2)]$,the score is 7 points.
When $EC_1 \in [(-0.3,-0.2) \cup (0.2,0.3)]$, the score is 5 points.
When $EC_1 \in [(-0.4,-0.3) \cup (0.3,0.4)]$, the score is 3 points.
When $EC_1 \in [(-0.5,-0.4) \cup (0.4,0.5)]$, the score is 1 point.
The specification of EC_2 is ±0.8mm and the scoring criteria is as follows:
When $EC_2 \in [(-0.16,0) \cup (0,0.16)]$,the score is 9 points.
When $EC_2 \in [(-0.32,-0.16) \cup (0.16,0.32)]$, the score is 7 points.
When $EC_2 \in [(-0.48,-0.32) \cup (0.32,0.48)]$, the score is 5 points.
When $EC_2 \in [(-0.64,-0.48) \cup (0.48,0.64)]$, the score is 3 points.
When $EC_2 \in [(-0.80,-0.64) \cup (0.64,0.80)]$, the score is 1 point.
The specification of EC3 is -50mm and the scoring criteria is as follows:
When $EC_3 \in (-10,0)$, the score is 9 points. When $EC_3 \in (-20,-10)$, the score is 7 points. When $EC_3 \in (-30,-20)$, the score is 5 points. When $EC_3 \in (-40,-30)$, the score is 3 points. When $EC_3 \in (-50,-40)$, the score is 1 point.
The specification of EC4 is -5%kg and the scoring criteria is as follows:
When $EC_4 \in (-1\%,0)$, the score is 9 points. When $EC_4 \in (-2\%,-1\%)$, the score is 7 points. When $EC_4 \in (-3\%,-2\%)$, the score is 5 points. When $EC_4 \in (-4\%,-3\%)$, the score is 3 points. When $EC_4 \in (-5\%,-4\%)$, the score is 1 point.
According to the above scoring criteria, 4 suppliers' scores on *EC* are obtained in Table 7:

Table 7, Supplier scores on EC

Supplier	EC_1	EC_2	EC_3	EC_4
A_1	5	7	3	3
A_2	3	7	5	9
A_3	9	5	3	5
A_4	7	5	3	7

Due to the abstractness of the supplier's performance on SC, the scoring criteria related to the use of fuzzy numbers are not detailed here. Through the evaluation of the expert group, the score of the suppliers on SC is shown in Table 8:

Table 8, Supplier Scores on SC

Supplier	SC_1	SC_2	SC_3	SC_4
A_1	7	3	3	3
A_2	5	7	5	3
A_3	5	5	3	7
A_4	7	9	3	1

Based on this, the weighted score of the suppliers on EC can be calculated according to formula 5 as shown in Table 9:

Table 9, Z_{p1} results

Z_{11}	Z_{21}	Z_{31}	Z_{41}
8.50	12.11	11.18	11.39

The weighted score of the suppliers on SC can be calculated according to formula 6 as shown in Table 10:

Table 10, Z_{p2} results

Z_{12}	Z_{22}	Z_{32}	Z_{42}
6.38	9.99	9.72	9.09

Finally, calculate the total score of each supplier by formula 7 as shown in Table 11:

Table 11, Z_p results

Z_1	Z_2	Z_3	Z_4
14.88	22.10	20.90	20.48

According to Table 10, it can be seen that the total score of no. 2 supplier is the highest. The order of supplier selection by bidding group should be $A_2 \succ A_3 \succ A_4 \succ A_1$, where superior means. If only one supplier is selected, supplier no. 2 should be selected; if alternate is considered, supplier no. 2 and supplier no. 3 should be selected.

Summary

Through the analysis and calculation of the case, we can see that QFD method can complete the supplier selection with considering of suppliers' engineering characteristics and service characteristics, which proves the applicability and practicability of the model and the strategy can be improved by changing the weight. This method is helpful to improve the scientific, objective and accurate decision-making, and has great practical value.

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