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Method of the Enterprise’s Supplier Selection Based on Interval Value TOPSIS of Triangular Fuzzy Numbers

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Supplier selection is an important task when an enterprise establishes a supply chain. For an enterprise’s raw material supply, the assessment index system of supplier selection is established by analyzing its basic principles and method. An enterprise’s multi-objective supplier selection method is put forward based on triangular fuzzy numbers and interval value TOPSIS. This method can fully reflect the requirements of supplier capacity and enterprise demands, and provides an effective approach for enterprises to select suppliers.

1. Introduction

Supply chain management is one of the important competitive strategies of modern enterprises. The main purpose for supply chain management is to integrate different enterprise resources in the supply chain so as to respond to market changes and satisfy the customer needs. Supplier selection is one of the important tasks for an enterprise to establish a supply chain because the supplier has a great influence on product cost and quality, technology and timescales of new product launch. Based on research data, the sales volume for the products and services purchased by one enterprise from its suppliers accounts for 50 to 90 percent of the sales of the whole enterprise. Thus, scientifically and reasonably selecting an enterprise’s suppliers is crucial of its operation management.

There are many decision-making methods to evaluate a supplier. This paper concludes the types of supplier selection methods and analyzes characteristics and application conditions of various decision-making methods by summing up previous supplier selection and decision-making methods employed experts. Furthermore, it proposes supplier selection methods based on TOPSIS of triangular fuzzy numbers and will provide helpful references for enterprise supply chain management and supplier selection.

2. Principles and Methods of Supplier Selection

2.1 Principles

Generally speaking, the buyer and the supplier have a mutually conflicting relation, which has been replaced by the cooperative win-win relation between them in modern chain management.

Houshyar(1992) divided the systematized supplier selection procedures into the following steps: a. Supplier selection criteria; b. Establishment of supplier selection criteria; c. Weight of supplier selection criteria; d. Processing of supplier selection data; e. Calculation and ranking of the supplier’s performances. Therefore, the supplier selection is a series of management and decision behaviors such as screening of candidate suppliers, establishment of evaluation criteria, weight of evaluation criteria, candidate suppliers’ performances in evaluation criteria and overall assessment in their alternative schemes.

According to Carter’s study (1995, it is found that when the relation between the supplier and the buyer becomes more intimate with more cooperative relations, the buyer tends to reduce the number of suppliers and enter into strategic alliance with the remaining suppliers. Forster (1961) thought the buyer intended to cooperate with a single supplier in place of previous cooperative relations with several suppliers. So according to these studies on methods of supplier selection, Swift (1995) classified the different evaluation factors in single supplier or several supplier selection. It is found by F-test that the buyer pays more attention to price, quality and delivery time in selection of several suppliers however, in the single supplier selection more

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emphasis is placed upon the technology-supporting effectiveness and reliability of products. In addition, the buyer selecting several suppliers pays more attention to price, while the buyer selecting the single supplier lays more emphasis on total cost of products.

After studying considerations in selection of suppliers in the US automobile industry, Choi et al. (1996) performed analysis on questionnaires in their study. The results show that the main influencing factors for the manufacturers to select direct suppliers are the suppliers' design and manufacturing capacity. When they select indirect suppliers what manufacturers often consider is price. In the analysis, supplier selection encompasses 26 evaluation factors, and eight factors are selected through the factorial analysis.

It is known from the above literatures that indexes for supplier selection and evaluation are mostly aimed at specific industries and the general supplier selection method is difficult to determine. The supplier selection standard has developed to multi-objective orientation. Thus, the indexes determined in the study should be the important evaluation criteria recognized by scholars generally so as to gain the enterprise's supplier evaluation criteria in consideration of the practical domestic iron and steel industry.

2.2 Method of Supplier Selection

Different enterprises have different criterion in selection of suppliers: the selecting criterion for enterprises taking the cost advantage as their competitive strategy is mainly cost; selecting criterion for the ones taking quality differentiation as their competitive strategy is mainly in consideration of quality. It is known by summing up foreign and domestic supplier selection methods in literatures that the supplier evaluation modes are mostly probability and statistics, mathematical programming, supplier profile analysis, multi-attribute utility, cost proportion, analytical hierarchy process, multi-objective decision-making method and fuzzy comprehensive judgment.

The multi-objective decision-making method is to simplify the complex evaluation of multi-attribute utility function as evaluation of a series of single-attribute utility numbers to get value function and weight and performances of suppliers. This method allows for the following criteria: price and delivery time, production technology and quality, financial status and reputation, company's organization and conception, and after-sale services and cooperation; the supplier selection system is structured based on multi-objective decision to gain ranking of suppliers' performances.

3. Design of Multi-Attribute Decision Method Based on Interval Number TOPSIS

3.1 Interval Number Decision Matrix and its Normative Approach

(1) Structuring the Interval Number Decision Matrix

The multi-attribute decision for an attribute as an interval number is set as a scheme set, $x=(x_1,\ x_2,\cdots x_n)$ and $u=(u_1, u_2,\cdots u_m)$ which is an attribute value. The scheme x_i is measured by the attribute vale u_j to get x_i's attribute value $\tilde{a}_{ij}$ ($\tilde{a}_{ij}=\left[a_{ij}^L, a_{ij}^U\right]$)on u_j, so as to constitute the decision matrix $\tilde{A}=(a_{ij})_{n\times m}$.

As for multi-attribute decision of an interval number, the decision matrix information $\tilde{A}=(a_{ij})_{n\times m}$ is obtained first, then it is processed normatively to get the normative decision matrix $\tilde{R}=(\tilde{r}_{ij})_{n\times m}$, .

(2) Normative Approach

In order to eliminate influences of different physical dimensions on decision results, the decision matrix $\tilde{A}$ is translated into a nominative matrix $\tilde{R}=(\tilde{r}_{ij})_{n\times m}$, where, $\tilde{r}_{ij}=\left[r_{ij}^L, r_{ij}^U\right]$. As the decision attributes are divided into efficiency and cost types, $I_j(j=1,2)$ is set as the subscript sets representing efficiency and cost types. The normative methods for two types are as follows:

$$\tilde{r}_{ij}=\tilde{a}_{ij}/\sum_{j=1}^{n}\tilde{a}_{ij},\quad i\in N, j\in I_1 \tag{1}$$

$$\tilde{r}_{ij}=(1/\tilde{a}_{ij})/\sum_{j=1}^{n}(1/\tilde{a}_{ij}),\quad i\in N, j\in I_2 \tag{2}$$

Based on the rules of operation related to interval numbers, Formulas (1) and (2) are rewritten as follows:

$$\left.\begin{aligned} r_{ij}^{L} &= a_{ij}^{L} \Big/ \sum_{i=1}^{n} a_{ij}^{U}, \\ r_{ij}^{U} &= a_{ij}^{U} \Big/ \sum_{i=1}^{n} a_{ij}^{L}, \end{aligned} \quad i \in N,\ j \in I_1, \right\} \tag{3}$$

$$\left.\begin{aligned} r_{ij}^{L} &= (1/a_{ij}^{U}) \Big/ \sum_{i=1}^{n} (1/a_{ij}^{L}), \\ r_{ij}^{U} &= (1/a_{ij}^{L}) \Big/ \sum_{i=1}^{n} (1/a_{ij}^{U}), \end{aligned} \quad i \in N,\ j \in I_2, \right\} \tag{4}$$

3.2 Determination of the Weight of Interval Number Attribute Based on Triangular Fuzzy Numbers

(1) Determining the weight vector $\omega = (\omega_1, \omega_2, \cdots \omega_m)$ of attribute values

The fuzzy AHP proposed by Buckley (1985) is adopted in this paper to establish a fuzzy positive reciprocal matrix by the triangular fuzzy numbers according to experts' opinions. Then, the weight is solved by the fuzzy geometric method to calculate the total fuzzy score of schemes via hierarchical series. Finally, the priority level of the schemes is ranked based on the total fuzzy score of schemes.

3.3 TOPSIS Method Whose Attribute Value is an Internal Value

(1) Determine the positive and negative ideal points ($\tilde{y}^{+}, \tilde{y}^{-}$) of interval number attribute values based on weighting a normative interval number matrix.

$$\tilde{y}_j^{+} = \left[\tilde{y}_j^{+L}, \tilde{y}_j^{+U}\right] = \left[\max_i (y_{ij}^{L}), \max_i (y_{ij}^{U})\right], \quad j \in M$$

$$\tilde{y}_j^{-} = \left[\tilde{y}_j^{-L}, \tilde{y}_j^{-U}\right] = \left[\min_i (y_{ij}^{L}), \min_i (y_{ij}^{U})\right], \quad j \in M$$

(2) Calculate the distances of each scheme to positive and negative ideal points respectively:

$$D_i^{+} = \sum_{j=1}^{m} \left\| \tilde{y}_{ij} - \tilde{y}_j^{+} \right\| = \sum_{j=1}^{m} \left[\left| y_{ij}^{L} - y_j^{+L} \right| + \left| y_{ij}^{U} - y_j^{+U} \right| \right], \quad i \in N$$

$$D_i^{-} = \sum_{j=1}^{m} \left\| \tilde{y}_{ij} - \tilde{y}_j^{-} \right\| = \sum_{j=1}^{m} \left[\left| y_{ij}^{L} - y_j^{-L} \right| + \left| y_{ij}^{U} - y_j^{-U} \right| \right], \quad i \in N$$

(3) Calculate the close degree $c_i (i \in N)$ of each scheme to the ideal point, and make a sequence of the schemes based on close degrees. The bigger c_i is, the better the scheme x_i is.

$$c_i = \frac{D_i^{-}}{D_i^{-} + D_i^{+}}, \quad i \in N$$

4. Determination and Calculation of Assessment Index System for Enterprises to Select Suppliers

4.1 Establishment of Assessment Index System for Enterprises to Select Suppliers

(1) Design and Handout of Questionnaires

There were 14 indexes as shown in Table 1 for the enterprise's supplier selection determined preliminarily based on research results, and the supplier selection index system was established according to questionnaires and factor analysis.

In this paper, the middle-level and senior executives, purchasing staff and QC personnel in medium and large iron and steel enterprises were selected as respondents. They scored these indexes by 5 levels (1-Leaving out; 2-Considered but not important; 3-Important; 4-Very important; 5-Extremely important). The investigators gave explanations to the respondents about questionnaires in person, and asked them to complete the questionnaires on site. The questions that the respondents couldn't understand were explained by the investigators. In this way 3580 questionnaires were given out, and 257 completed questionnaires were collected, of which 232 were effective. The recovery rate and effective rate for questionnaires were up to 73.43% and 66.29% respectively.

Table 1 Descriptive statistics of questionnaires

Index	Mean value	SD
Enterprise qualification	2.9515	0.9020
Guarantee and compensation	2.6153	0.6984
Product quality	3.1403	0.8834
Geographic position	3.0217	0.6389
Service attitude	1.7280	1.0190
Response to service	3.0809	0.7984
Cooperative relation	3.1359	0.6169
Pricing policy	2.6200	0.5220
Historical performance	3.1729	0.5915
Production equipment and capacity	1.7804	0.8300
Coordination mechanism	3.0160	1.1084
Reputation in the industry	1.8611	0.8074
Guarantee for transportation	2.6766	0.3156
Delivery rate on time	2.7766	1.3156

The "Service Attitude", "Production Equipment and Capacity" and "Reputation in the Industry" are below 2 based on their mean values and standard deviations. This indicates that the investigators generally consider that importance degree for these indexes is lower. Thus, the other 11 indexes should be reserved as shown in Table 2.

Table 2: Index weight for the enterprise's supplier selection

1-level Index	Weight	2-level weight	Weight	Total weight
Basic requirement C_1	0.4131	Enterprise qualification C_{11}	0.3844	0.1588
		Historical performance C_{12}	0.2945	0.1217
		Geographic position C_{13}	0.3211	0.1326
Requirement for product C_2	0.3125	Pricing policy C_{21}	0.3121	0.0975
		Delivery rate on time C_{22}	0.2322	0.0726
		Product quality C_{23}	0.1814	0.0567
		Guarantee for transportation C_{24}	0.2743	0.0857
Requirement for service C_3	0.2744	Cooperative relation C_{31}	0.2145	0.0589
		Coordination mechanism C_{32}	0.3181	0.0873
		Response to service C_{33}	0.2153	0.0591
		Guarantee and compensation C_{34}	0.2521	0.0692

(2) Factor Analysis

The factor analysis was carried out by the other 11 indexes to determine the enterprise's supplier selection index system structure. Applicability of factor analysis was tested at first. The test methods for the applicability were: the Bartlett Test of Sphericity and the Kaiser-Meyer-Olkin (KMO) tests.

SPSS18.0was used to conduct the KMO and Bartlett Sphericity tests for the supplier selection index questionnaire results. The testing result KMO value was 0.814. This value was used for the exploratory factor analysis based on standards offered by Statistician Kaiser. Meanwhile, the accompanied probability from the Bartlett Sphericity test was 0.000, less than the significant level of 0.05. Thus, the null hypothesis for Bartlett t sphericity test was refused, and the exploratory factor analysis could be carried out.

There are two criteria for determining factor number by the exploratory factor analysis: one is selecting the factor whose characteristic value is greater than 1; the other is that the accumulated SD contribution rate is greater than 70%. The variables have factor load capacity in common factors. The factor load capacity determines a variable should be assigned to the common factor. Generally speaking, it is significant if the absolute value of the factor load capacity is greater than 0.3; it is more important if the capacity is greater than 0.3; it is very significant if the capacity is greater than 0.5. Thus, the factor load value being greater than 0.4 means that it has significant load capacity to determine the items contained for each factor. The value was less than 0.4 but rounded, the load for the factors is shown in Table 3.

(3) Explanation of Index Naming

Determine the enterprise's supplier selection index system based on results of factor analysis.

Table 3 Load matrix for supplier selection index factors

Supplier selection index	**Component**		
	1	2	3
Enterprise qualification	0.7399		
Historical performance	0.6929		
Geographic position	0.5479		
Pricing policy		0.7258	
Delivery rat on time		0.6258	
Product quality		0.5860	
Guarantee for transportation		0.4956	
Cooperative relation			7.0223
Coordination mechanism			6.6706
Response to service			6.3730
Guarantee and compensation			5.1579
SD explanation proportion	**34.17%**	**21.66%**	**17.15%**
Total SD explanation proportion	**72.98%**		

(4) Weight Determination of the Enterprise's Supplier Selection Evaluation Index System
10 experts were employed to carry out fuzzy judgment to relative importance at different levels. The index weight was calculated by Formulas (5—9) as shown in Table 2.

4.2 Cases of the Enterprise's Supplier Selection
(1) Problem Description
One enterprise determined three potential suppliers (named as x1, x2 and x3 respectively) by preliminary screening. Experts were employed to evaluate each index, and the scores were represented by interval values (scoring by the hundred mark system); the original data was obtained.
(2) Normalize original data and get the weighting normative decision matrix based on the index weight, and the weighting normative matrix is available, i.e. $\tilde{Y} = (y_{ij})_{n\times m}$.

(3) Determine positive and negative ideal points $\tilde{y}^+, \tilde{y}^-$ of interval number attribute values:

$$\tilde{y}_j^+ = [0.01813, 0.02635],\ \tilde{y}_j^- = [0.00421, 0.00633]$$

(4) Calculate each supplier to be evaluated and the distance between positive and negative ideal points; calculate the close degree $c_i (i \in N)$ for each evaluation object to the ideal point and make a sequence for suppliers by their close degrees.

Table 4: Close degrees for evaluation object's ideal points

Supplier to be evaluated	x_1	x_2	x_3
D_i^+	0.1756	0.2238	0.1812
D_i^-	0.1622	0.1426	0.2119
c_i	0.4802	0.3891	0.5391

It can be seen from the calculated results that $c_3 > c_1 > c_2$. The conclusions are that Supplier 3 is the best option with Supplier 1 ranked second and Supplier 2 ranked poorest.

5. Conclusions

Aiming at the enterprise's practical supplier selection, a multi-subjective supplier selection method for enterprises is established based on interval value TOPSIS and triangular fuzzy numbers. The method describes the supplier level by the interval numbers, which more accords with the enterprise's practical supplier evaluation. In addition, by determining index weight by triangular fuzzy numbers the information is more complete and can be directly applied to practical supplier selection. The study results show that this method can measure the enterprise's supplier level effectively, and provide valuable information for the enterprise in the selection of suppliers.

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