社団法人　情報処理学会　研究報告
IPSJ SIG Technical Reports

2005－ＩＣＳ－139（31）
2005／3／16

# サプライチェーンシステムにおける供給者選択:ファジー決定アプローチ

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# Supplier Selection in Supply Chain System: A Fuzzy Decision Approach

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**Abstract** Supplier selection plays an important role in supply chain management. Since supplier selection is involved in a lot of uncertain factors (both subjective and objective), fuzzy decision technique will be an attention-worthy one in effectively exploring the issue. This paper, based on the analysis of characteristic of supply chain management, establishes an evaluation system with a set of supplier-selection indices. Then, an approach using fuzzy decision making and AHP is presented for supplier selection in supply chain management. Finally, a case study is conducted to illustrate the analysis process of the approach.

**Keyword** Supplier Selection, Fuzzy Decision, Supply Chain Management

## 1. Introduction

Many manufacturers and service providers are seeking the strategic cooperation with suitable suppliers to improve their own purchasing management since the development and application of core capabilities are more and more emphasized in enterprise business. It was reported that the costs of raw materials and components account for about 70% of product values. And about 30% of quality faults and 80% of delivery postponement are resulted from suppliers. These data mean that suppliers' effectiveness plays an important role in the successful management of a whole supply chain. In addition, highly competitive globalization markets make supplier selection geographically worldwide. Furthermore, manufacturing resources are required to quickly and efficiently integrate into an entity with the introduction and application of various advanced manufacturing paradigms, which makes the issue of supplier selection become more complex and important in supply chain management (SCM).

Supplier selection is involved in many factors which are both subjective and objective. It is undoubtedly one type of decision that determines the long-term viability of an enterprise. So far, as a modern multi-criterion decision-making method, the Analytic Hierarchy Process (AHP) has been being regarded as a most widely used method of supplier selection. Since supplier selection is involved in various kinds of uncertain factors, however, the integration of fuzzy decision technique into AHP will be an attention-worthy path for effectively exploring the issue. This paper, based on the analysis of a supplier-selection index-assessment system, proposes a set of supplier-selection indices. Then, an approach using fuzzy decision and AHP is presented for the supplier selection in supply chain systems. Finally, an example is applied to illustrate the analysis process of this approach.

## 2. Index Assessment System

The appropriate determination of supplier assessment index is a key to whether suitable suppliers can be found in SCM. Dickson[1] studied the issue and distinguished more than 20 factors involving supplier assessment index. From the practical data provided by 170 purchasing managers, it was found that three most important factors are quality, cost (price) and delivery in selecting suppliers. In general, some high-impact factors should be considered in deciding a suitable supplier[2].

We investigated the statistical data provided by manufacturing enterprises and searched for relative references. At the same time, as many factors as possible are analyzed affecting supplier selection in a supply chain system. Finally, a set of assessment indices for supplier selection (as shown in Table 1) is established, which is based on four important ways: time, cost, robustness and scope of change.

Table 1. Index System for Supplier Assessment

| First-level Index | Second-level Index | Sign |
|---|---|---|
| Quality $U_1$ | Quality management system audit | $U_{11}$ |
| | Product test and satisfactory rate | $U_{12}$ |
| | Percentage of workforce with technical qualification | $U_{13}$ |
| Price(Cost) $U_2$ | | |
| Delivery $U_3$ | | |
| Capability $U_4$ | Design capability | $U_{41}$ |
| | Process capability | $U_{42}$ |
| | Production capability | $U_{43}$ |
| Technology & Standard $U_5$ | Automation Level | $U_{51}$ |
| | Information level | $U_{52}$ |
| | Standardization | $U_{53}$ |
| | Application of advanced manufacturing technology | $U_{54}$ |
| Reputation $U_6$ | Supply history | $U_{61}$ |
| | Reputation at the same occupation | $U_{62}$ |
| | Service | $U_{63}$ |
| | Training & supporting | $U_{64}$ |

From the index assessment system it can be easily found that the assessment for these indices is usually flexible and fuzzy. Some indices have to be determined by Delphi method or stochastic investigation although the others can be obtained from relative statistical data. So, we propose a fuzzy integrated decision approach by using fuzzy decision-making and AHP to solve such a problem of fuzzy evaluation.

## 3. Fuzzy Integrated Assessment Model

Fuzzy integrated assessment is mainly involved in four kinds of elements: factor set ($U$), evaluation set ($V$), single-element evaluation matrix ($R$), and weighted vector ($W$). The procedure for establishing the model is described as follows.

### 3.1. Establishing supplier assessment index set

By using improved Delphi method, gathering necessary information, and consulting relevant experts, at first, supplier assessment index set ($U$) is established. Then the set is further divided into $n$ sub-set: $U_1, U_2, \cdots, U_n$, that is,

$$U = \{U_i\}, \quad i = 1,2,\cdots,n. \tag{1}$$

where the following conditions are met:

$$\bigcup_1^n U_i = U, \quad U_i \cap U_j = \emptyset, \quad i \neq j. \tag{2}$$

For the problem of interest as shown in Table 1, the number of factors $n = 6$.

### 3.2. Determining index-weighted set ($W$)

AHP and grey relation analysis are used to build up weighted matrix for comparison and judgment, that is,

$$W = (w_1, w_2, \cdots, w_n), \qquad \sum_1^n w_i = 1 \tag{3}$$

$$W_i = (w_{i1}, w_{i2}, \cdots, w_{im}), \qquad \sum_{j=1}^m w_{ij} = 1, \tag{4}$$

where $w_{ij}$ denotes the weighted value of second-level index $U_{ij}$ under first-level index $U_i$, and $m$ denotes the number of the second-level indices for $U_i$.

### 3.3. Setting up evaluation set ($V$) and score set ($F$)

Evaluation set ($V$) can be decided by practical situations. For the problem of interest, it is set up on a five-point scale, that is,

$$V = (v_1, v_2, v_3, v_4, v_5) = (excellent, better, good, satisfactory, poor).$$

And the corresponding score set:

$$F = (1.0,\ 0.8,\ 0.6,\ 0.4,\ 0.2).$$

### 3.4. Second-level fuzzy assessment for $U_i$

At first, single-element assessment is made for each element in $U_i$. Then fuzzy assessment matrix ($R_i$) is obtained by

$$R_i = \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1k} \\ r_{i21} & r_{i22} & \cdots & r_{i2k} \\ \vdots & \vdots & \vdots & \vdots \\ r_{im1} & r_{im2} & \cdots & r_{imk} \end{bmatrix} \tag{5}$$

where $k$ denotes the number of scales in $V$ and $r_{imj}$ the degree that $U_{im}$ is subordinate to $v_j$. From the comprehensive assessment for $U_i$, it can be obtained that:

$$B_i = W_i \cdot R_i = W_i \cdot \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1k} \\ r_{i21} & r_{i22} & \cdots & r_{i2k} \\ \vdots & \vdots & \vdots & \vdots \\ r_{im1} & r_{im2} & \cdots & r_{imk} \end{bmatrix} = (b_{i1}, b_{i2}, \cdots, b_{ik}) \tag{6}$$

where $b_{it}(t = 1,2,\cdots,k)$ is treated on basis of the operator of $M(\cdot, \oplus)$ [3], that is,

$$b_{it} = \bigvee_{j=1}^{k} (w_{it} \wedge r_{ijt}) . \tag{7}$$

After $B_i$ is normalized, we can get $B_i'$ and thus $B = (B_1', B_2', \cdots, B_n')^T$.

### 3.5. Fuzzy integrated assessment for $U$

If $Z$ represents the results of first-level fuzzy integrated assessment, then we have

$$Z = W \cdot B = W \cdot (B_1', B_2', \cdots, B_n')^T = (z_1, z_2, \cdots, z_m) \tag{8}$$

And we can further obtain the comprehensive assessment score of the supplier, that is,

$$C = Z \cdot F^T \tag{9}$$

### 3.6. Deciding optimal supplier(s)

Based on the final score of each supplier, we can easily queue all candidate suppliers up and distinguish suitable supplier(s) among them.

## 4. CaseAnalysis

To illustrate the analysis process of the above model, an example dealing with an important component used in a set of large-size air-separation equipment is described below.

The manufacturer has screened three candidate suppliers $(S_1, S_2, S_3)$ for the possible strategic cooperation in the production of the important component. All of them are dispersed geographically. The objective is to decide a most suitable supplier among the three candidate ones.

Since the index assessment system is shown as Table 1, as for this issue we have:

$$U = (U_1, U_2, U_3, U_4, U_5, U_6)$$
$$U_1 = (U_{11}, U_{12}, U_{13}, U_{14})$$
$$U_4 = (U_{41}, U_{42}, U_{43})$$
$$U_5 = (U_{51}, U_{52}, U_{53}, U_{54})$$
$$U_6 = (U_{61}, U_{62}, U_{63}, U_{64})$$

And some original data for supplier $S_1$ is given in Tab.2.

Table 2. Some Original Data for Supplier $S_1$

| $r_{it1}$ | $r_{it2}$ | $r_{it3}$ | $r_{it4}$ | $r_{it5}$ |
|---|---|---|---|---|
| 0.0 | 0.0 | 0.7 | 0.2 | 0.1 |
| 0.1 | 0.2 | 0.4 | 0.3 | 0.0 |
| 0.0 | 0.3 | 0.5 | 0.1 | 0.1 |
| 0.1 | 0.2 | 0.3 | 0.2 | 0.2 |
| 0.0 | 0.3 | 0.4 | 0.2 | 0.1 |
| 0.1 | 0.2 | 0.4 | 0.3 | 0.0 |
| 0.2 | 0.1 | 0.5 | 0.2 | 0.0 |
| 0.2 | 0.2 | 0.5 | 0.1 | 0.0 |
| 0.1 | 0.2 | 0.1 | 0.5 | 0.1 |
| 0.1 | 0.2 | 0.3 | 0.3 | 0.1 |
| 0.0 | 0.1 | 0.5 | 0.2 | 0.2 |
| 0.0 | 0.2 | 0.6 | 0.2 | 0.0 |
| 0.6 | 0.1 | 0.1 | 0.1 | 0.1 |
| 0.2 | 0.5 | 0.1 | 0.2 | 0.0 |
| 0.3 | 0.1 | 0.4 | 0.2 | 0.0 |
| 0.1 | 0.2 | 0.2 | 0.3 | 0.2 |

At first, AHP and grey relation analysis is applied to evaluate the index-weighted set, based on necessary information and investigation, such as, the product's production requirements, the manufacturer's expectation for high-impact factors (quality, price and delivery), and so on. The details of collecting, processing and analyzing original data and of the application analysis process of the model for the example are neglected here. A limited number of processed results is given as follows for reference.

$$W = (0.26, 0.28, 0.18, 0.11, 0.09, 0.08)$$
$$W_1 = (0.32, 0.53, 0.15)$$
$$W_4 = (0.17, 0.31, 0.52)$$
$$W_5 = (0.16, 0.48, 0.18, 0.18)$$
$$W_6 = (0.37, 0.23, 0.32, 0.08))$$

By using Eqs.(5), (6) and (7), the fuzzy integrated assessment matrix for supplier $S_1$ is obtained by

$$B^{(1)}=\begin{bmatrix}0.053 & 0.151 & 0.511 & 0.238 & 0.047\\ 0.100 & 0.200 & 0.300 & 0.200 & 0.200\\ 0.000 & 0.300 & 0.400 & 0.200 & 0.100\\ 0.183 & 0.169 & 0.483 & 0.165 & 0.000\\ 0.064 & 0.182 & 0.358 & 0.296 & 0.100\\ 0.372 & 0.200 & 0.204 & 0.171 & 0.053\end{bmatrix}$$

Thus, we have the following evaluation results for supplier $S_1$.

$$Z^{(1)}=W\cdot B^{(1)}=(0.097,0.200,0.391,0.212,0.100).$$

$$C^{(1)}=Z^{(1)}\cdot F^T=0.596$$

As for the other two candidate suppliers, $S_2$ and $S_3$, the fuzzy evaluation scores are $C^{(2)}=0.662$ and $C^{(3)}=0.637$, respectively.

From the above fuzzy evaluation scores it can be found that the strategic cooperation with supplier $S_2$ is most perfect in carrying out the task.

## 5. Concluding Remarks

The fuzzy integrated assessment index system presented in the paper for supplier selection in supply chain systems should be modified and adjusted according to practical situations that it is applied. However, the basic assessment procedures will remain unchangeable.

The combination of fuzzy assessment with AHP makes the evaluation of some qualitative indices quantitative and helps decrease the subjectivity in traditional assessment for supplier selection.

In addition, special attention should be paid to the relational matrix and weight matrix in the fuzzy integrated assessment index model for supplier selection. Both of them are closely related to the objectivity and accuracy of the model in practical application.

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