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# Research on the supplier selection of a supply chain based on entropy weight and improved ELECTRE-III method

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# Research on the supplier selection of a supply chain based on entropy weight and improved ELECTRE-III method

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On the background of economic globalisation, market competition is no longer the competition between enterprises, but it is the competition between supply chains. Supplier selection is the basis of supply chain cooperation, and is also the key factor to improve the competitive power of a supply chain. A novel method, which combines entropy weight and an improved ELECTRE-III method, is proposed to deal with supplier selection of supply chains. The research states at home and abroad are firstly analysed, and on the foundation of the relative literature, the indicator systems are constructed and the corresponding objective weight of each indicator based on entropy is calculated. Then the threshold is confirmed and the harmoniousness index and the unharmoniousness index are calculated. Next, the outranking relation is calculated and evaluated. Last, the suppliers are ranked based on the net advantage value of each project. Finally, the case analysis proves that the process of this method is clear and the application of it is convenient.

**Keywords:** supply chain; entropy weight; ELECTRE-III; outranking relation

## 1. Introduction

On the background of economic globalisation, market competition is no longer the competition between enterprises, but the competition between supply chains. Research on supply chain management has attracted people's widespread interest, and has obtained rich research results (Johnson 1995, Ho *et al*. 2002, Pontrandolfo *et al*. 2002, Chen and Paulraj 2004, Flynn and Flynn 2005, Wu 2006, Chandra *et al*. 2007, Field and Sroufe 2007, Foster and Ogden 2008, Lee and Kimz 2008, Wadhwa *et al*. 2008, Hsu *et al*. 2009, Jain *et al*. 2009). Supplier selection is the key factor to improve the whole competitive power of a supply chain. So selecting a supplier reasonably well will affect directly reduction of the cost, increase of flexibility, and improvement of competition power (Ma *et al*. 2000). Supplier selection has caused the concern of many scholars and industry at home and abroad and an amount of research about it has been made. At present, aspects of research on the supplier selection mainly include: the index system and the evaluation method.

About the aspect of index system: Weber *et al*. (1991) summarised the research achievements of the supplier selection criteria after the paper of Dickson (Dickson 1966) was presented, and discovered that price, delivery, quality and ability criteria were mentioned in most papers after analysing 74 concerned papers in the literature about

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supplier selection; Johnson (1995) adopted an enterprise performance evaluation method to consider that time, quality, cost and service were the key factors of success of the factors affecting supplier selection; Ma *et al*. (2000) proposed a synthetic evaluation index system in the environment of supply chain management, and classified the main factors into four kinds: enterprise performance, professional structure and produce ability, quality system, and enterprise environment; Qian *et al*. (2000) pointed out that time, quality, cost and service were the key factors of success when selecting a supplier in an agile virtual enterprise; Ma (2002) proposed that the criteria of supplier selection are composed of nine evaluation indices: quality, price, service, geographical position, technology lever, supply capacity, economic benefits, delivery, and market effect degree.

About the aspect of evaluation methods: Zhu (2004) used the buyer and seller two-phase game model to simplify DEA and constructed an efficiency interval to evaluate suppliers; Kumar *et al*. (2006) use fuzzy optimisation theory to evaluate suppliers; Wang *et al*. (2002) proposed a Euclid norm evaluation method based on the relative inferior membership degree; Ma and Wang (2002) proposed a grey relation model to solve the evaluation index weight; Bai and Cui (2006) proposed supplier evaluation based on TOPSIS. However, these methods are all based on the compensating accumulation principle, that is, the weakness of a certain index can be compensated by another index, such as the weakness of price can be compensated by service, but in practice, the compensation of weakness is only in a certain range. When the attribute is very weak, it is not compensated, such as the price of a certain supplier exceeds other suppliers too much (for example, over two times), the supplier may not be considered; on the other hand, if the difference in the price is small, we can consider that the suppliers ignore the difference in the attribute of price. ELECTRE-III is a decision evaluation method based on a precedence relation; it can satisfy different evaluation requirements by defining undifferentiated threshold, strict superior threshold and rejection threshold. ELECTRE-III has strong flexibility and can satisfy the requirement of supplier selection.

Based on the above reasons, this paper proposes an improved ELECTRE-III method based on a precedence relation to evaluate suppliers. Firstly, the corresponding objective weight of each index based on entropy is calculated; then the threshold is confirmed and the harmoniousness index and the unharmoniousness index are calculated, and the outranking relation is calculated and evaluated; and last, the suppliers are ranked based on the net advantage value of each project.

## 2. Evaluation index system for supplier selection

Based on the above research, and combining the practical aspects of supply chain management, this paper considers that constructing an evaluation index system for supplier selection should follow six principles: comparability, objectivity, comprehension, reliability, flexibility, and easy operation, and meanwhile minimising the evaluation index to make the evaluation process financially feasible and definition definite. This paper considers that the nine indices which Ma (2002) proposed have strong operation, and can be used as the basic indices of supplier selection. The nine indices are: quality, price, service, geographical position, technology lever, supply capacity, economic benefits, delivery, and market effect degree. Besides, this paper further extends the index system shown in Table 1. In practice evaluation, corresponding index can be chosen according to different status.

## 3. The improved ELECTRE-III method based on entropy weight

The ELECTRE (ELimination Et Choix Traduisant la Realité – elimination and choice translation reality) method was first put forward by Benayoun, Roy and Sussman in the 1960s (Benayoun *et al.* 1966). Then Roy (1968, 1978) and Rey and Bertier (1971, 1973) developed the method to form the ELECTRE family which have different varieties. Among them, the ELECTRE-III method is mainly used to solve the ranking problem of the alternatives whose data is certainty data.

### 3.1 *The determination of index weight*

Suppose that there are $m$ evaluation objects (suppliers) $A = (a_1, a_2, \ldots, a_m)$, $n$ evaluation indices $C = (c_1, c_2, \ldots, c_n)$, the evaluation index values of each supplier form matrix $X$, where $x_{ij}$ represents the $j$th index evaluation value of the $i$th supplier.

(1) Data normalisation

There are many normalised methods, we choose the following method:

$$r_{ij} = \tilde{x}_{ij} \Big/ \sqrt{\sum_{i=1}^{m} \tilde{x}_{ij}^2}, \quad 1 \le i \le m,\ 1 \le j \le n. \tag{1}$$

Here:

$$\tilde{x}_{ij} = \begin{cases} x_{ij}, & \text{if } x_{ij} \text{ is a benifit index} \\ 1/x_{ij}, & \text{if } x_{ij} \text{ is a cost index} \end{cases}.$$

(2) Calculate decision information entropy value

There are many methods to determine the index weight, such as expert opinion survey method or AHP, but these methods have very large subjective factors when determining the evaluation index weight. This paper adopts information entropy to determine the weight to avoid the effect of subjective factors. Entropy is a measure that uses probability theory to measure the uncertainty of information. It shows that the more dispersive the data, the bigger the uncertainty. The decision information of each index can be expressed by entropy value $E_j$:

$$E_j = -K \sum_{i=1}^{m} r_{ij} \ln r_{ij}, \quad 1 \le i \le m,\ 1 \le j \le n,\ 0 \ln 0 \equiv 0. \tag{2}$$

Here, $m$ is the number of evaluation objects, and $K = 1/\ln m$.

(3) Calculate difference degree

The difference degree can be calculated as follows:

$$G_j = 1 - E_j, \quad 1 \le j \le n. \tag{3}$$

(4) Calculate entropy weight $w$:

$$w_j = G_j \Big/ \sum_{j=1}^{n} G_j \quad 1 \le j \le n. \tag{4}$$

### 3.2 *The evaluation steps of ELECTRE-III method*

(1) Construct threshold.

In order to construct the fuzzy outranking relation, the ELECTRE-III method brings in three thresholds (Zhang *et al.* 2006): (a) undifferentiated threshold, $q_j$; (b) strict superior threshold, $p_j$; and (c) rejection threshold, $v_j$. Their meanings are as follows:

- **Undifferentiated threshold** $q_j$: when the difference between attribute values of alternative $a_i$ and alternative $a_k$ in criterion $c_j$ is not more than $q_j$, that is, when $r_{ij} + q_j \geq r_{kj}$ and $r_{kj} + q_j \geq r_{ij}$, alternative $a_i$ and alternative $a_k$ are considered to be undifferentiated in criterion $c_j$.
- **Strict superior threshold** $p_j$: when the difference between attribute values of alternative $a_i$ and alternative $a_k$ in criterion $c_j$ is more than $p_j$, that is, when $r_{ij} \geq r_{kj} + p_j$, alternative $a_i$ is considered to be a strict superior to alternative $a_k$. If $r_{kj} + q_j < r_{ij} \leq r_{kj} + p_j$, then alternative $a_i$ is considered to be a weak superior to alternative $a_k$.
- **Rejection threshold** $v_j$: when the difference between attribute values of alternative $a_k$ and alternative $a_i$ in criterion $c_j$ is no less than $v_j$, that is, when $r_{kj} \geq r_{ij} + v_j$, alternative $a_i$ is not considered to be superior to alternative $a_k$ on the whole.

For given random criterion $c_j$, $0 < q_j < p_j < v_j$. The thresholds $q_j$, $p_j$ and $v_j$, need to be determined according to the practice of concrete problems and the risk attitude of the decision-maker. The following principles are advised in this paper:

(a) Undifferentiated threshold $q_j$:

Undifferentiated threshold $q_j =$ (the max attribute value $-$ the min attribute value) $*$ certain percent, the percent is usually: 5–10%. Of course, it can be regulated appropriately according to the risk attitude of the decision-maker. In this paper, the percent is taken as 10%.

(b) Strict superior threshold $p_j$:

Strict superior threshold $p_j =$ undifferentiated threshold $q_j *$ certain multiple, the multiple is usually 3–10. In this paper, the multiple is taken as 3.

(c) Rejection threshold $v_j$:

Rejection threshold $v_j =$ (the max attribute value $-$ the min attribute criterion value) $*$ certain multiple. The multiple is usually 3–5. In this paper, the multiple is taken as 3.

(2) Calculate the harmoniousness index and the unharmoniousness index.

Single index harmoniousness index:

$$SD_j(i,k) = \begin{cases} 1, & \text{if } r_{ij} + q_j \geq r_{kj} \\ 0, & \text{if } r_{ij} + p_j \leq r_{kj}\,, \\ (r_{kj} - (r_{ij} + p_j))/(q_j - p_j), & \text{otherwise} \end{cases} \tag{5}$$

where $SD_j(i,k)$ represents the degree of supporting the judgement that alternative $a_i$ is superior to alternative $a_k$ in index $c_j$.

Single index unharmoniousness index:

$$D_j(i,k) = \begin{cases} 0, & \text{if } r_{ij} + p_j \geq r_{kj} \\ 1, & \text{if } r_{ij} + v_j \leq r_{kj} \\ (r_{kj} - (r_{ij} + p_j))/(v_j - p_j), & \text{otherwise} \end{cases}, \tag{6}$$

where $D_j(i,k)$ represents the measure which rejecting the judgement that alternative $a_i$ is superior to alternative $a_k$ in index $c_j$.
Overall harmoniousness relation:

$$C(i,k) = \frac{\sum_{j=1}^{n} w_j SD_j(i,k)}{\sum_{j=1}^{n} w_j} = \sum_{j=1}^{n} w_j SD_j(i,k), \quad i,k = 1,2,\ldots,m. \tag{7}$$

Outranking relation that is credit degree index:

$$S(i,k) = \begin{cases} C(i,k), & \text{if } D_j(i,k) \leq C(i,k), \forall j \\ C(i,k) \prod_{\{j \in J: D_j(i,k) > C(i,k)\}} \frac{1-D_j(i,k)}{1-C(i,k)}, & \text{otherwise} \end{cases}, \tag{8}$$

where $S(i,k)$ represents the measure which supports the judgement that alternative $a_i$ is superior to alternative $a_k$ in the whole level.

(3) Calculate the total score, and determine the ranking relation of each alternative.

For all the alternative pairs in alternative sets, consider the outranking relations which satisfy the above conditions. In these relations, measure the good and bad of alternative $a_i$ according to the difference between the number of direction arca flowing from $a_i$ and the number of direction arcs flowing into $a_i$, by classifying and comparing many times to finally determine the ranking. In this paper, the net advantage value in the literature (Zhang *et al.* 2006) is used as the basis of judging the score of alternatives. The formula of the net advantage value is as follows:

$$\delta_k = \sum_{\substack{i=1 \\ i \neq k}}^{m} S(i,k) - \sum_{\substack{i=1 \\ i \neq k}}^{m} S(k,i), \quad k = 1,2,\ldots,m, \tag{9}$$

where $\delta_k$ represents the satisfaction scores of alternatives. The more the scores, the higher the satisfaction degree.

## 4. Application case

This case adopts the nine indices system which was proposed by Ma (2002), and the data also comes from Ma (2002). A certain enterprise needs to choose a partner from six suppliers of parts and components. Product quality, product price, service, geographical position, technology level, supply ability, economic benefits, delivery, and market effect degree are chosen as the nine evaluation criteria. Among them, product quality, technology level, supply ability, economic benefits, delivery, and market effect degree are benefit indexes, the bigger, the better; product price, service, geographical position are cost indexes, the smaller, the better. The evaluation values of each index are shown in Table 2.

(1) The decision steps are as follows:

(i) According to Table 2, the initial evaluation matrix is obtained as:

$$X = \begin{bmatrix} 0.79 & 335 & 3.2 & 15 & 0.12 & 230 & 0.12 & 0.83 & 0.13 \\ 0.91 & 268 & 1.4 & 37 & 0.25 & 130 & 0.08 & 0.96 & 0.15 \\ 0.99 & 304 & 1.9 & 22 & 0.09 & 200 & 0.14 & 0.99 & 0.20 \\ 0.97 & 270 & 2.0 & 19 & 0.33 & 180 & 0.09 & 0.87 & 0.21 \\ 0.86 & 310 & 0.8 & 26 & 0.20 & 150 & 0.15 & 0.80 & 0.12 \\ 0.95 & 303 & 2.7 & 8 & 0.19 & 170 & 0.17 & 0.91 & 0.19 \end{bmatrix}.$$

(ii) According to Formula (1), the normalised matrix is obtained as:

$$R = \begin{bmatrix} 0.353 & 0.360 & 0.186 & 0.405 & 0.231 & 0.523 & 0.380 & 0.378 & 0.312 \\ 0.406 & 0.450 & 0.424 & 0.164 & 0.481 & 0.295 & 0.253 & 0.437 & 0.360 \\ 0.442 & 0.397 & 0.313 & 0.276 & 0.173 & 0.455 & 0.443 & 0.451 & 0.479 \\ 0.433 & 0.447 & 0.297 & 0.320 & 0.635 & 0.409 & 0.285 & 0.396 & 0.503 \\ 0.384 & 0.389 & 0.742 & 0.234 & 0.385 & 0.341 & 0.475 & 0.365 & 0.288 \\ 0.424 & 0.398 & 0.220 & 0.759 & 0.366 & 0.386 & 0.538 & 0.415 & 0.455 \end{bmatrix}.$$

Table 1. Index of supplier evaluation.

| Content | | Index | |
|---|---|---|---|
| A1 | Technology level | B1 | Production development ability |
| | | B2 | Production quality |
| | | B3 | Production reliability |
| | | B4 | Quality certification level in product system |
| A2 | Service level | B5 | Price |
| | | B6 | Delivery |
| | | B7 | Credit degree |
| | | B8 | The satisfaction degree of after service |
| A3 | Managing ability | B9 | Finance status |
| | | B10 | Supply ability |
| | | B11 | Collaboration ability |
| | | B12 | Management ability |
| | | B13 | Development ability |
| A4 | Enterprise environment | B14 | Politics and law environment |
| | | B15 | Economic and technical environment |
| | | B16 | Natural geographical environment |
| | | B17 | Social and cultural environment |
| | | B18 | The compatibility of enterprise culture |
| | | B19 | The compatibility of management system |

(iii) According to Formulae (2), (3), and (4), the entropy weight of each index is calculated as:

$$W = \{0.143 \quad 0.143 \quad 0.059 \quad 0.050 \quad 0.082 \quad 0.132 \quad 0.119 \quad 0.143 \quad 0.128\}$$
$$q = \{0.0200 \quad 0.0001 \quad 0.0938 \quad 0.0098 \quad 0.0240 \quad 10.0000 \quad 0.0090 \quad 0.0190 \quad 0.0090\}$$
$$p = \{0.0600 \quad 0.0002 \quad 0.2813 \quad 0.0294 \quad 0.0720 \quad 30.0000 \quad 0.0270 \quad 0.0570 \quad 0.0270\}$$
$$v = \{0.6000 \quad 0.0022 \quad 2.8125 \quad 0.2939 \quad 0.7200 \quad 300.0000 \quad 0.2700 \quad 0.5700 \quad 0.2700\}.$$

(iv) The overall harmoniousness index is:

$$C = \begin{bmatrix} 1.000 & 0.352 & 0.332 & 0.395 & 0.454 & 0.195 \\ 0.698 & 1.000 & 0.414 & 0.467 & 0.752 & 0.499 \\ 0.828 & 0.746 & 1.000 & 0.768 & 0.853 & 0.749 \\ 0.738 & 0.819 & 0.672 & 1.000 & 0.822 & 0.751 \\ 0.772 & 0.434 & 0.453 & 0.217 & 1.000 & 0.396 \\ 0.868 & 0.620 & 0.626 & 0.686 & 0.941 & 1.000 \end{bmatrix}.$$

(v) The credit index is:

$$S = \begin{bmatrix} 1.000 & 0.352 & 0.332 & 0.395 & 0.454 & 0.195 \\ 0.698 & 1.000 & 0.414 & 0.467 & 0.752 & 0.499 \\ 0.828 & 0.746 & 1.000 & 0.768 & 0.853 & 0.749 \\ 0.738 & 0.819 & 0.672 & 1.000 & 0.822 & 0.751 \\ 0.772 & 0.434 & 0.453 & 0.205 & 1.000 & 0.396 \\ 0.868 & 0.620 & 0.626 & 0.686 & 0.941 & 1.000 \end{bmatrix}.$$

(vi) The net advantage value is as follows:

$$\delta = \{-2.176 \quad -0.140 \quad 1.447 \quad 1.279 \quad -1.561 \quad 1.151\}.$$

Table 2. Value of supplier evaluation.

| Supplier | Product quality | Product price (¥) | Service (hour) | Geographical position (km) | Technology level | Supply ability (piece) | Economic benefits | Delivery | Market effect degree |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.79 | 335 | 3.2 | 15 | 0.12 | 230 | 0.12 | 0.83 | 0.13 |
| 2 | 0.91 | 268 | 1.4 | 37 | 0.25 | 130 | 0.08 | 0.96 | 0.15 |
| 3 | 0.99 | 304 | 1.9 | 22 | 0.09 | 200 | 0.14 | 0.99 | 0.20 |
| 4 | 0.97 | 270 | 2.0 | 19 | 0.33 | 180 | 0.09 | 0.87 | 0.21 |
| 5 | 0.86 | 310 | 0.8 | 26 | 0.20 | 150 | 0.15 | 0.80 | 0.12 |
| 6 | 0.95 | 303 | 2.7 | 8 | 0.19 | 170 | 0.17 | 0.91 | 0.19 |

So the ranking of the six suppliers is: 3, 4, 6, 2, 5, 1.

(2) Result analysis

The TOPSIS method is used to rank the supplier, and get the ranking result: $3, 4, 6, 2, 5, 1$. It is the same as the result in the above method, indicating the validity of the above method. However, it is different from the result in Ma (2002), the primary reason is that the entropy weight is a mistake in Ma's (2002) calculations. If we use the entropy weight in Ma (2002), the result by using the method in this paper would also be the same as the result obtained in Ma (2002).

## 5. Conclusions

Supplier selection is the basis of supply chain collaboration. This paper used an improved ELECTRE-III method based on entropy weight to construct a supplier selection model. In this paper, the objective weight was calculated based on information entropy to avoid the subjectivity of weight determined, and make the evaluation result more objective and more practical; the undifferentiated threshold, strict superior threshold and rejection threshold were defined based on the improved ELECTRE-III method, thus it can be considered that the alternatives are undifferentiated, compensated or rejected in a certain range to remedy the defects of the complete compensated evaluation method; and then the harmoniousness index, the unharmoniousness index and the outranking relation were calculated; and last, the suppliers were ranked based on the net advantage value of each project. The application of the case indicated that the method is convenient for operation and easy to be spread and applied.

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