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Topsis Multiple Attribute Decision Support Analysis for Supplier Selection Problem in a Group Decision Making

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ABSTRACT

Supplier selection is a multiple attribute decision making (MADM) problem that must be done in a group decision making. Since the decision makers' (DMs) preferences on alternatives or attributes of suppliers are often uncertain, supplier selection becomes more difficult, and the impact of the DMs priority on the decision making must be considered. TOPSIS (technique for order performance by similarity to ideal solution) method is one of the methods used to study uncertainty. In this paper, the TOPSIS approach has been used to deal with the supplier selection problem in a group decision making and consider relative importance of each DM. The work procedure is as follows: firstly, the weighs and ratings of attributes for all supplier alternatives are described by each DM. Secondly, relative importance of each DM is considered to establish the decision matrix. Thirdly, the separation measure is used to determine the ranking order of all alternatives of supplier, and then a linear programming model is established to find the optimum order quantities. Finally, an example of a selection problem of supplier is used to illustrate the proposed approach.

Keywords: *Group decision making problem, multiple attribute decision making (MADM),relative importance of decision makers, supplier selection, TOPSIS*

Introduction

With the globalization of the economic market and the development of information technology, many companies consider that a well designed and implemented supply chain management (SCM) system is an important tool for increasing competitive advantage (Choi et al., 2007). The supplier selection problem becomes one of the most critical components in SCM (Hong et al., 2005; Ndubisi et al., 2005; Lasch & Janker, 2005). In the past, several methods have been proposed to solve the supplier selection problem, the main ones being the linear weighting methods (LW) (Thompson, 1990; Timmerman, 1986), the analytic hierarchy process (AHP) (Barbarosoglu & Yazgac, 1997; Narasimhan, 1983), the analytic network process (ANP)(Sarkis & Talluri, 2000), total cost approaches(Monezka & Trecha, 1998; Smytka & Clemens, 1993) and mathematical programming (MP) techniques(Buffa & Jackson, 1983; Chaudhry et al, 1993). Although linear weighting is a very simple method, it depends heavily on human judgement and also the attributes are weighted equally, which rarely happens in practice. The drawback of MP is that it requires arbitrary aspiration levels and cannot accommodate subjective attributes (Khorramshahgol et al., 1988). AHP, on the other hand, cannot effectively take into account risk and uncertainty in estimating the supplier's performance because it presumes that the relative importance of attributes affecting supplier performance is known with certainty (Dyer et al., 1992).

Supplier selection is affected by several conflicting factors, and must be performed in a group decision making. As a result, supplier selection is a multiple attribute decision making (MADM) problem. Depending on the purchasing situations, criteria have varying importance and the relative importance of DMs is different that must be considered. DMs always express their preferences on alternatives or on the attributes of suppliers, which can be used to help rank the suppliers or select the most desirable ones. The preference information on alternatives of suppliers and their attributes belongs to the DMs' subjective judgements. In conventional MADM methods, the ratings and weights of the attributes are known precisely (Delgado et al., 1992; Hwang &

Yoon, 1981; Kaufmann & Gupta, 1991). Generally, DMs' judgements are often uncertain and cannot be estimated by an exact numerical value. Thus, the problem of selecting suppliers has many uncertainties and becomes more difficult.

TOPSIS is a useful technique in dealing with MADM problems in uncertainty for a group decision making (Shih et al., 2007). In addition, through this method, relative importance of DMs and attributes can be considered. It helps DMs organize the problems to be solved, and carry out analysis, comparisons and rankings of the alternatives.

In this paper, TOPSIS is extended for group decision making to consider the relative importance of DMs, and to take into account both tangible and intangible factors in choosing the best supplier under an uncertain environment. The work procedure is briefly listed as follows: firstly, the rating of attributes for all supplier alternatives are described by each DM. Secondly, relative importance of each DM is considered to establish the decision matrix. Thirdly, the separation measure is used to determine the ranking order of all alternatives of supplier, and then a linear programming model is established to find the optimum order quantities. Finally, an example of a selection problem of supplier is used to illustrate the proposed approach.

This paper is organized as follows: Section2 describes TOPSIS concepts whereas Sectionintroduces the proposed approach. In Section, the proposed approach is applied to the supplier selection problem, and finally, conclusions are drawn in Section.

TOPSIS Concepts

The technique for order preference by similarity to ideal solution (TOPSIS) was first developed by Hwang and Yoon (1981), based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative-ideal solution (NIS) for solving a multiple criteria decision making problem. Thus, the best alternative should not only have the shortest distance from the positive ideal solution, but also the largest distance from the negative ideal solution. In short, the ideal solution is composed of all best values attainable of criteria, whereas the negative ideal solution is made up of all worst values attainable of criteria. The calculation processes of this method are explained in the next sections.

Proposed Approach

The section is divided into two parts. First, calculation of final score of each supplier is shown and then the linear programming model is built in order to assign order quantities among the suppliers.

Calculation of the Overall Score of Each Supplier

TOPSIS is proposed for prioritizing the preference of supplier that is very suitable for solving the group decision making problem in an uncertain environment. Assume that $S=\{S_1,S_2,\ldots,S_m\}$ is a discrete set of m possible supplier alternatives. $Q=\{Q_1,Q_2,\ldots,Q_n\}$ is a set of n attributes of suppliers. The attributes are additively independent. $w=\{w_1,w_2,\ldots,w_n\}$ is the vector of attribute weights so that they must sum to 1 otherwise it is normalized. In this paper, the attribute ratings of suppliers for the subjective attributes and the attribute weights are considered as linguistic variables., the attribute ratings G can be expressed by the 1–5 scale shown in Table1. The attribute weights can also be expressed by the 1–9 scale shown in Table. The quantitative attributes are scaled using the same unit (their own real number). It is assumed that there are K DMs with relative importance of W^1, W^2, W^3, and W^k respectively. It is only indicated that the weights can be calculated by AHP or Simple Multi Attribute Rating Technique (SMART) methods.

Table 1: The Scale of Attribute Ratings ***G***

Scale	*G*
Poor (P)	1
Medium poor (MP)	3
Fair (F)	5
Medium good (MG)	7
Good (G)	9
Intermediate values between the two adjacent judgments	2,4,6,8

Table 2: The Scale of Attribute Weights ***w***

Scale	*w*
Very very low (VVL)	0.050
Very low (VL)	0.125
Low (L)	0.175
Medium low (ML)	0.225
Medium (M)	0.275
Medium high (MH)	0.325
High (H)	0.375
Very high (VH)	0.425
Very very high (VVH)	0.475

The procedures are summarized as follows:

Step 1

Form a committee of DMs to express their preferences on attribute weights and ratings of suppliers:

i. Use linguistic variables (Table 2) to identify the attribute weights of suppliers. The attribute weight of attribute Q_j can be calculated in Eq. (1). It is assumed that DMs' weight is not considered to identify the attribute weights of suppliers.

$$W_j = \frac{1}{K}\left[W_j^1 + W_j^2 + \ldots + W_j^K\right] \tag{1}$$

where $W_j^K (j = 1,2,\ldots, n)$ is the attribute weight of Kth DMs and can be described by

linguistic variables.

ii. Use linguistic variables (Table 1) to identify the attribute ratings of suppliers for the subjective attributes. Then, the rating value can be calculated in Eq. (2) by considering DMs' weight.

$$G_{ij} = \frac{1}{K}\left[G_{ij}^1 \times w^1 + G_{ij}^2 \times w^2 + \ldots + G_{ij}^K \times w^k\right] \tag{2}$$

where $G_{ij}^K (i = 1,2,\ldots,m, j = 1,2,\ldots,n)$ is the attribute rating value of Kth w^k DMs, and where is the

Kth DMs' weight.

Step 2

$$D = \begin{bmatrix} G_{11} & G_{12} & \cdots & G_{1n} \\ G_{21} & G_{22} & \cdots & G_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ G_{m1} & G_{m2} & \cdots & G_{mn} \end{bmatrix} \tag{3}$$

Establish the decision matrix D that the structure of the matrix can be expressed in Eq. (3).

Step 3

Normalize the evaluation matrix in Eq. (4): the process is to transform different scales and units among various criteria into common measurable units to allow comparisons across the criteria.

$$D^{*} = \begin{bmatrix} G^{*}_{11} & G^{*}_{12} & \cdots & G^{*}_{1n} \\ G^{*}_{21} & G^{*}_{22} & \cdots & G^{*}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ G^{*}_{m1} & G^{*}_{m2} & \cdots & G^{*}_{mn} \end{bmatrix} \tag{4}$$

Assume G_{ij} to be of the evaluation matrix *D* of alternative *i* under evaluation criterion *j* then an element G^{*}_{ij} of the normalized evaluation matrix D^{*} can be calculated with the following formula :

$$G^{*}_{ij} = \frac{G_{ij}}{\sqrt{\sum_{i=1}^{m} \left(G_{ij}\right)^{2}}} \tag{5}$$

Step 4

Establish the weighted normalized decision matrix in Eq. (6). Considering the different importance of each attribute, the weighted normalized evaluation matrix $_{*}$ can be calculated by multiplying the normalized evaluation matrix with its associated G_{ij} weight to W_{j} obtain the result $V_{ij} = G^{*}_{ij} \times W_{j}$ The weighted normalized decision $D^{*'}$ matrix is:

$$D^{*'} = \begin{bmatrix} V_{11} & V_{12} & \cdots & V_{1n} \\ V_{21} & V_{22} & \cdots & V_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ V_{m1} & V_{m2} & \cdots & V_{mn} \end{bmatrix} \tag{6}$$

Step 5

Establish the ideal solutions $S^{\max} = \left\{G_1^{\max}, G_2^{\max}, \ldots, G_n^{\max}\right\}$ and negative-ideal solutions $S^{\min} = \left\{G_1^{\min}, G_2^{\min}, \ldots, G_n^{\min}\right\}$ in Eqs. (7)-(8) respectively.

$$S^{\max} = \left\{\left[\max_{1\le i\le m} V_{ij} \middle| j \in J_1\right], \left[\min_{1\le i\le m} V_{ij} \middle| j \in J_2\right]\right\} \tag{7}$$

$$S^{\min} = \left\{\left[\min_{1\le i\le m} V_{ij} \middle| j \in J_1\right], \left[\max_{1\le i\le m} V_{ij} \middle| j \in J_2\right]\right\} \tag{8}$$

where J_1 is associated with the benefit criteria and J_2 is associated with the cost criteria; $j=1,\ldots,n$.

Step 6

Calculate the separation of each alternative from S_i^+ the ideal solution and negative ideal solution in

Eqs. (9)-(10) respectively. That means S_i^- is the distance (in an Euclidean sense) of each

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - G_i^{\max}\right)^2} \tag{9}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - G_i^{\min}\right)^2} \tag{10}$$

alternative from the ideal solution and is the distance from the negative-ideal solution and are defined as:

where $i=1,\ldots,m$.

Step 7

The relative closeness to the ideal solution is calculated in Eq. (11).

$$C_i^* = \frac{S_i^-}{S_i^+ + S_i^-} \quad i = 1,\ldots,m \tag{11}$$

where $0 \le C_i^* \le 1$ The larger the index value, the better the performance of the

alternative.

Step 8

Rank the preference order. When C_i^* is bigger, the ranking order of *Si* is better. Otherwise, the ranking order is worse.

If there are no constraints, choose the maximum score supplier and buy all demand from this supplier and stop. Otherwise go to step 3.2.

Build the Linear Programming Model

If there are some constraints such as suppliers' capacity, quality, etc., use the suppliers' ratings as coefficients of an objective function in linear programming to assign order quantities to the suppliers such that the total value of purchasing (TVP) becomes maximum. The objective function and constraints of this linear programming are as follows:

Notations

Ci final ratings of *i*th supplier, X*i* Order quantity for *i*th supplier, V*i* Capacity of *i*th supplier, *D*

Demand for the period, q_i Defect percent of ith supplier, P Buyer's maximum acceptable defect rate

Objective function
As C_i and X_i, respectively, denote the ratings and the numbers of purchased units from the ith supplier and maximising the total value of purchasing is desired, the objective function is in Eq. (12).

$$Max(TVP) = \sum_{i=1}^{n} C_i X_i \tag{12}$$

Constraints
The important constraints of the problem are supplier's capacity, buyer's demand and quality (Ghodsypour and Brien, 1998), which are formulated as follows:

Capacity constraint: As vendor i can provide up to V_i units of the product and its order quantity (X_i) should be equal or less than its capacity, these constraints are in Eq. (13)

$$X_i \leq V_i, i = 1,2,...,n. \tag{13}$$

Demand constraint: As sum of the assigned order quantities to n vendors should meet the buyer's demand, it can be stated in Eqs. (14)

$$\sum_{i=1}^{n} X_i = D \tag{14}$$

Quality constraint: Since P is the buyer's maximum acceptable defect rate and q_i is the defect rate of the ith vendor, the quality constraint can be shown in Eq. (15)

$$\sum_{i=1}^{n} X_i q_i \leq P\,D \tag{15}$$

Application

Calculate the Overall Score of Each Supplier

There are five suppliers $S_i=\{S_1,S_2,\ldots,S_5\}$ selected as alternatives against five attributes $Q_j=\{Q_1,Q_2,\ldots,Q_5\}$. The five attributes are price, quality includes defects, on-time delivery, performance history and technical capability respectively. *Q3*, *Q4* and *Q5* are benefit attributes, the greater values being better. Whilst *Q1*, *Q2* are cost attributes, the smaller values are better. Performance history (*Q4*) and technical capability (*Q5*) are subjective criteria that are considered as linguistic variables, and other attributes, i.e. criteria scaled using the same unit (their own real number) respectively. The qualitative information is shown in Table 3. In addition, the buyer's demand is 1000 units and the maximum acceptable defect rate is 0.0205.

Table 3: Suppliers' Quantitative Information

S_i	Q_1	Q_2	Q_3	Capacity(V_i)
S_1	30	0.03	0.95	200
S_2	40	0.05	0.98	700
S_3	50	0.01	0.85	300
S_4	45	0.06	0.92	500
S_5	38	0.02	0.90	450

Step 1

Make the weights of attributes Q_1, Q_2, Q_3, Q_4 and Q_5. A committee of four DMs, D_1, D_2, D_3 and D_4 has been formed to express their preferences and to select the best suppliers. According to Eq. (1), the evaluation values of attribute weights from four MDs can be obtained and the results are shown in Table 4.

Table 4: Attribute Weights for Five Suppliers

Q_i	D_1	D_2	D_3	D_4	w_i	Normalized w_i
Q_1	H	L	L	VL	0.212	0.191
Q_2	H	M	ML	VL	0.25	0.225
Q_3	VH	VL	VVL	ML	0.206	0.185
Q_4	L	VL	VVL	MH	0.168	0.151
Q_5	VH	L	M	ML	0.275	0.247
		TOTAL			1.1125	1.000

Step 2

Make attribute rating values for five supplier alternatives. According to Eq. (2), the results of attribute rating values are shown in Table.5.

Note: the four DMs' weight are 0.365, 0.255, 0.19 and 0.19 that are

denoted as: W^1, W^2, W^3 *and* W^4 respectively.

Step 3

Establish the decision matrix. According to Eq. (3), the decision matrix of suppliers is obtained.

Step 4

Establish the normalized decision table. According to the normalized decision matrix shown in Eq. (4), the normalized decision matrix of suppliers is shown in Table 6.

Table 5: Attribute Rating Values for Supplier

Q_i	S_i	D_1	D_2	D_3	D_4	G_{ij}
Q_1						
	S_1	30	30	30	30	7.500
	S_2	40	40	40	40	10.00
	S_3	50	50	50	50	12.50
	S_4	45	45	45	45	11.25
	S_5	38	38	38	38	9.500
Q_2						
	S_1	0.03	0.03	0.03	0.03	0.080
	S_2	0.05	0.05	0.05	0.05	0.013
	S_3	0.01	0.01	0.01	0.01	0.003
	S_4	0.06	0.06	0.06	0.06	0.015
	S_5	0.02	0.02	0.02	0.02	0.005
Q_3						
	S_1	0.95	0.95	0.95	0.95	0.238
	S_2	0.98	0.98	0.98	0.98	0.245
	S_3	0.85	0.85	0.85	0.85	0.213
	S_4	0.92	0.92	0.92	0.92	0.230
	S_5	0.90	0.90	0.90	0.90	0.225
Q_4						
	S_1	G	P	MP	MP	1.170
	S_2	MP	MP&F	MP&F	MP&F	0.909
	S_3	F	F	MP&F	F	1.203
	S_4	G	G	G	MG	2.155
	S_5	P&MP	MG	G	MG	1.389
Q_5						
	S_1	G	MP	P	MP	1.203
	S_2	MP	MP&F	F	F	1.004
	S_3	G	G	MP&G	MG&G	2.155
	S_4	G	MG	MG	G	2.028
	S_5	MP	G	MG	MG	1.513

Table 6: Normalized Decision Table

S_i	Q_1	Q_2	Q_3	Q_4	Q_5
S_1	0.326	0.346	0.461	0.366	0.327
S_2	0.435	0.577	0.476	0.284	0.273
S_3	0.543	0.115	0.413	0.376	0.587
S_4	0.489	0.693	0.447	0.677	0.552
S_5	0.413	0.231	O.437	0.435	0.412

Step 5
Establish the weighted normalized decision table. According to the weighted normalized decision matrix shown in Eq. (6), the weighted normalized decision matrix of suppliers is shown in Table 7.

Table 7: Weighted Normalized Decision Table

S_i	Q_1	Q_2	Q_3	Q_4	Q_5
S_1	0.062	0.078	0.085	0.055	0.081
S_2	0.083	0.130	0.088	0.043	0.068
S_3	0.104	0.026	0.077	0.057	0.145
S_4	0.093	0.156	0.083	0.102	0.137
S_5	0.079	0.052	O.081	0.066	0.102

Step 6
Establish the ideal supplier S^{max} and negative-ideal supplier S^{min} a referential supplier.

According to Eqs. (7)-(8), the ideal and negative ideal supplier are shown as follows, respectively:

$$S^{max} = [0.062, ..., 0.026, ..., 0.088, ..., 0.102, ..., 0.145]$$

$$S^{min} = [0.104, ..., 0.156, ..., 0.077, ..., 0.043, ..., 0.068]$$

Step 7
Calculate the separation of each alternative from the ideal and negative ideal supplier. According to Eqs. (9)-(10), the results of the separation are shown as follows:

$$S_1^+ = 0.095 \quad S_2^+ = 0.144 \quad S_3^+ = 0.062 \quad S_4^+ = 0.134 \quad S_5^+ = 0.065$$

$$S_1^- = 0.090 \quad S_2^- = 0.035 \quad S_3^- = 0.152 \quad S_4^- = 0.092 \quad S_5^- = 0.115$$

Step 8
Calculate the relative closeness of each alternative to the ideal supplier. According to Eq. (11), the results of the relative closeness are shown as follows:

$$C_1^* = 0.488 \quad C_2^* = 0.197 \quad C_3^* = 0.709 \quad C_4^* = 0.406 \quad C_5^* = 0.639$$

Step 9
Rank the order of five suppliers. According to step 8, the result of ranking order is shown as follows:

$$S_3 > S_5 > S_1 > S_4 > S_2$$

Calculate the Optimum Order Quantities

Establish the linear programming in order to find the best order quantities. According to Eq. (12), the objective function is as follows:

Max (TVP) = 0.488X1 + 0.197X2 + 0.709X3+0.406X4 + 0.639X5

According to Eqs. (13), (14), (15), the constraints are as follows, respectively:

$$0 \leq X1 \leq 400;\ 0 \leq X2 \leq 700; 0 \leq X3 \leq 600; 0 \leq X4 \leq 500; 0 \leq X5 \leq 500$$

$$X1 + X2 + X3 + X4 + X5 = 1000$$

$$.03X1 + 0.05X2 + 0.01X3 + 0.06X4 + 0.02X5 \leq 20.5$$

This LP problem is solved using Solver from Microsoft Excel. The results of the optimum order quantities are shown as follows:

$$X1 = 200; \quad X2 = 50; \quad X3 = 300; \quad X4 = 0; \quad X5 = 450$$

Conclusions

In this paper, the TOPSIS method is used to deal with the supplier selection problem in an uncertain environment, and consider the impact of DMs' weight on suppliers' rating. Supplier selection is a MADM problem. In conventional MADM methods, the ratings and the weights of attributes must be known precisely (Delgado et al., 1992; Hwang & Yoon, 1981; Kaufmann & Gupta, 1991). However, in many situations, DMs' judgements are often uncertain and cannot be estimated by an exact numerical value. Thus, the problem of selecting suppliers has many uncertainties and becomes more difficult. We can change our perspective and look at the real world from a different angle. System analysis can be treated from the point of view of the degree of information available. TOPSIS is one of the methods used to study the uncertainty of a system. This method is also flexible because the ratings of attributes can be described by both linguistic variables and exact numerical values.

In this article, TOPSIS is also used to consider both tangible and intangible factors and takes into account relative importance of DMs to select the most ideal supplier. An example of a supplier selection problem is used to illustrate the proposed approach. The result shows that the proposed approach is reliable and reasonable.

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