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Improvement of a Grey Based Method for supplier selection problem

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ABSTRACT

Purpose: In this article, we combine this new approach based on the concepts of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to evaluate and select the best supplier.

Design/methodology/approach: Supplier evaluation is a Multi-Attribute Decision-Making (MADM) problem that is affected by quantitative and qualitative factors, some of which may conflict. Since most of the input information is not known accurately, selecting the right suppliers becomes more difficult. Grey theory is one of the new mathematical methods used to analyze systems with uncertain and incomplete information.

Findings: Through this article, it is demonstrated that the improved method, which is used to solve the MADM problems for selecting the best supplier, is a good means of evaluation, and it appears to be more appropriate.

Practical implications: Grey theory is a new mathematical field that is one of the methods used to study the uncertainty of a system.

Originality/value: Through this article, it was demonstrated that the improved method, which is used to solve the MADM problems for selecting the best supplier, is a good means of evaluation, and it appears to be more appropriate.

Keywords: Production and operations management; Supplier selection; MADM; A grey based approach; TOPSIS concepts

1. Introduction

In manufacturing industries the raw materials and component parts can equal up to 70% of the product cost. In such circumstances the purchasing department can play a key role in cost reduction, and supplier selection is one of the most important functions of purchasing management [1].

When a relatively few parts are procured externally, the total demand can be provided by only one supplier. Such a sole sourcing scenario appears to be tenable especially in the last decade, which has seen an important shift in the sourcing strategy of many firms, moving from the traditional concept of having many suppliers to rely largely on one supplier with which a long term win–win partnership is established. In this situation, the decision consists of selecting one supplier for one order in order to meet the total buyer’s demand.

In this area, Li et al. [2] mentioned several methods that had been proposed to solve the supplier selection problem, the main ones being the analytic hierarchy process (AHP) [3,4], the analytic network process (ANP) [5], the linear weighting methods (LW) [6,7], total cost approach (TCA) [8,9] and mathematical programming (MP) techniques [10,11]. Drawbacks of the methods were explained by Li et al. [2] as following sentences. Although linear weighting is a very simple, it depends on human judgment heavily. Moreover the factors are weighted equally, which rarely happens in practice. MP requires arbitrary aspiration levels and cannot accommodate qualitative attributes [12]. On the other side, AHP can not effectively consider risk and uncertainty in estimating the alternative’s performance because it assumes that the relative importance of factors affecting supplier performance is known with certainty [13].

Supplier selection is a multiple attribute decision making (MADM) problem that is affected by several quantitative and qualitative factors, some of which may conflict. The DMs' preferences always expressed on alternatives or on the attributes of suppliers that can be used to help rank the suppliers. Generally, the input information, DMs' judgments, is often uncertain and cannot be estimated by an exact numerical value. Thus, supplier selection problem has many uncertainties and becomes more difficult.

To overcome this drawback, Li et al. [2] proposed a new grey based approach to deal with the problem of selecting suppliers under an uncertain environment. Grey theory, which was proposed by Deng in 1989 [14], is an effective mathematical means to deal with systems analysis characterized by incomplete and uncertain information. In grey theory [2], according to the degree of information, if the system information is fully known, the system is called a white system; if the information is unknown, it is called a black system. A system with information known partially is called a grey system. As Li et al. [2] mentioned, in recent years, a fuzzy-based approach has been proposed to deal with the supplier selection problem under uncertainty [15], but the advantage of grey theory over fuzzy theory [16] is that grey theory also considers the condition of the fuzziness; in other words, grey theory can deal flexibly with the fuzziness situation [2,14].

In Li's et al [1] method, the authors calculate a grey possibility degree between compared suppliers alternatives set and ideal referential supplier alternative to determine the ranking order of all alternatives of supplier and to select the ideal supplier based on grey numbers. The drawback of the method is that the negative ideal referential alternative is not considered to evaluate and rank the alternatives. Sometimes, the selected solution (here candidate supplier) which has the minimum grey possibility degree from the ideal solution may also has a lower grey possibility degree from the negative ideal solution as compared to other alternatives [18-20].

To overcome the drawback, we combine this approach based on the concepts of TOPSIS that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS) to evaluate suppliers. Through this article, we demonstrate that the combination method, which is used to solve the multiple attribute decision making problems for selecting the best supplier, is a good means of evaluation, and it appears to be more appropriate. This article is based on Li's et al. [2] article and we use its date, information and procedures.

The remainder of this paper is organized as follows. Section 2 describes preliminaries which include the concept of TOPSIS, the grey theory concepts and grey number comparison. The combination of the grey model with TOPSIS concepts for selecting the supplier is proposed in Section 3. Then, in Section 4, an illustrative example presents applying the proposed approach to the supplier selection problem, after which we discuss and show how the method based on the ideas of TOPSIS is effective. Finally, conclusions are presented in Section 5. The methodology is illustrated in Fig. 1.

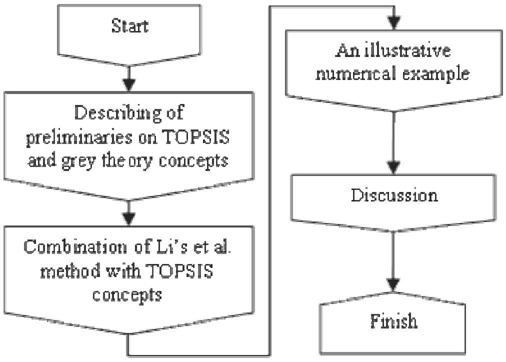

Fig. 1. Flowchart of the methodology

2. Preliminaries

2.1. TOPSIS for MADM

Multiple attribute decision making (MADM) is used to select an alternative from several alternatives according to various criteria. TOPSIS was first developed by Hwang and Yoon [17], based on the concept, the chosen alternative should have the shortest distance from the PIS and the farthest from the NIS for solving a multiple attribute decision making problem. Briefly, the positive ideal solution is made up of all best values attainable of criteria, whereas the negative ideal solution is composed of all worst values attainable of criteria.

2.2. Microstructure

Grey theory, proposed by Deng [14], is one of the new mathematical means that is an effective method used to solve uncertainty problems with incomplete information. In this section, we briefly review some relevant definitions and the calculation process in grey theory [2, 19]. $G=[\underline{G},\overline{G}]$ is an interval number if $G=[\underline{G},\overline{G}]=\{x|\underline{G}\le x\le\overline{G},\underline{G}\le\overline{G},\underline{G},\overline{G}\in R\}$ and $G=[\underline{G},\overline{G}]$ is also a positive interval number If $0\le\underline{G}\le\overline{G}$ [19]. Let $X=([\underline{G}_1,\overline{G}_1],[\underline{G}_2,\overline{G}_2],...,[\underline{G}_n,\overline{G}_n])$ be an n-dimension interval number column vector [1,19].

Definition 1 [19]. If $G_1=[\underline{G}_1,\overline{G}_1]$ and $G_2=[\underline{G}_2,\overline{G}_2]$ are two arbitrary interval numbers, the distance from $G_1=[\underline{G}_1,\overline{G}_1]$ to $G_2=[\underline{G}_2,\overline{G}_2]$ is:

$$|G_1-G_2|=\max(|\underline{G}_1-\underline{G}_2|,|\overline{G}_1-\overline{G}_2|) \tag{1}$$

Definition 2 [1]. If $G_1 = [\underline{G}_1, \overline{G}_1]$ and $G_2 = [\underline{G}_2, \overline{G}_2]$ are two arbitrary interval numbers, then:

$$G_1 + G_2 = [\underline{G}_1 + \underline{G}_2, \overline{G}_1 + \overline{G}_2] \tag{2}$$

Definition 3 [1]. If $G_1 = [\underline{G}_1, \overline{G}_1]$ and $G_2 = [\underline{G}_2, \overline{G}_2]$ are two arbitrary interval numbers, then:

$$G_1 - G_2 = [\underline{G}_1 - \overline{G}_2, \overline{G}_1 - \underline{G}_2] \tag{3}$$

Definition 4 [1]. If $G_1 = [\underline{G}_1, \overline{G}_1]$ and $G_2 = [\underline{G}_2, \overline{G}_2]$ are two arbitrary interval numbers, then:

$$G_1 \times G_2 = [\min(\underline{G}_1\underline{G}_2, \underline{G}_1\overline{G}_2, \overline{G}_1\underline{G}_2, \overline{G}_1\overline{G}_2), \max(\underline{G}_1\underline{G}_2, \underline{G}_1\overline{G}_2, \overline{G}_1\underline{G}_2, \overline{G}_1\overline{G}_2)] \tag{4}$$

Definition 5 [1]. If $G_1 = [\underline{G}_1, \overline{G}_1]$ and $G_2 = [\underline{G}_2, \overline{G}_2]$ are two arbitrary interval numbers, then:

$$G_1 \div G_2 = [\underline{G}_1, \overline{G}1] \times [\frac{1}{\underline{G}_2}, \frac{1}{\overline{G}_2}] \tag{5}$$

Definition 6 [19]. If k is an arbitrary positive reel number, and $G = [\underline{G}, \overline{G}]$ is an arbitrary interval number, then the number product between k and $G = [\underline{G}, \overline{G}]$ is:

$$K \cdot [\underline{G}, \overline{G}] = [K\underline{G}, K\overline{G}] \tag{6}$$

2.3. Comparison of Grey Numbers

Li et al [2] proposed a degree of grey possibility to compare the ranking of grey numbers.

Definition 7 [18]. If $G_1 = [\underline{G}_1, \overline{G}_1]$ and $G_2 = [\underline{G}_2, \overline{G}_2]$ are two arbitrary interval numbers, the possibility degree of $G_1 \le G_2$ can be expressed as follows:

$$p\{G_1 \le G_2\} = \frac{\max(0, L^* - \max(0, \overline{G}_1 - \underline{G}_2)}{L^*} \tag{8}$$

where $L^* = L(G_1) + L(G_2)$.

Definition 8. In this article, it is proposed that if $G_1 = [\underline{G}_1, \overline{G}_1]$ and $G_2 = [\underline{G}_2, \overline{G}_2]$ are two arbitrary interval numbers, the possibility degree of $G_1 \ge G_2$ is also expressed as follows

$$p\{G_1 \ge G_2\} = \frac{\max(0, L^* - \max(0, \overline{G}_2 - \underline{G}_1)}{L^*} \tag{9}$$

where $L^* = L(G_1) + L(G_2)$.

3. Combination of the grey based approach with TOPSIS concepts

The new method based on a grey possibility degree was proposed by Li et al. [2] to evaluate and select the best supplier. This method is very suitable for solving the group decision making problem with uncertain and incomplete information [2]. By considering the method, it can be concluded that there exists a certain degree of similarity between the input and operation of the model and TOPSIS technique. Thus, this paper is based on the TOPSIS concepts in combination with the application of this new grey based method to do multiple attribute evaluation.

In Li's et al. [2] paper, it was assumed that $S=\{S_1,S_2,\ldots,S_m\}$ is a discrete set of m possible supplier alternatives, and $Q=\{Q_1,Q_2,\ldots,Q_n\}$ is a set of n attributes of suppliers. The author also assume [2] the attributes are additively independent, and $W=\{W_1, W_2,\ldots, W_n\}$ is the vector of attribute weights. The attribute weights and ratings of suppliers are considered as linguistic variables [2]. Moreover, the same as Li's et al. [2] paper, the attribute ratings G and the attribute weights can be expressed in grey numbers by the 1÷7 scale shown in Table 1and Table 2, respectively.

Table 1.
The scale of attribute ratings G [2]

Scale	G
very poor (VP)	[0, 1]
poor (P)	[1, 3]
medium poor (MP)	[3, 4]
fair (F)	[4, 5]
medium good (MG)	[5, 6]
good (G)	[6, 9]
very good (VG)	[9, 10]

Table 2.
The scale of attribute weights w [2]

Scale	w
very low (VL)	[0.0, 0.1]
low (L)	[0.1, 0.3]
medium low (ML)	[0.3, 0.4]
medium (M)	[0.4, 0.5]
medium high (MH)	[0.5, 0.6]
high (H)	[0.6, 0.9]
very high (VH)	[0.9, 1.0]

In this section, firstly, Li's et al. [2] method and then its improvement are described.

3.1. The new grey based method

Based on Li's et al. [2] article, the procedures are summarized as follows:

Step 1

Form a committee of DMs and identify the attribute weights of suppliers. Assume that a decision group has K persons, then the attribute weight of attribute Q_j can be calculated in equation (9):

$$W_j = \frac{1}{K}[W_j^1 + W_j^2 + ... + W_j^K] \quad (9)$$

where $W_j^K (j = 1,2,...,n)$ is the attribute weight of K^{th} DMs and can be described by linguistic variable.

Step 2

Use linguistic variables for the ratings to make an attribute rating value. Then, the rating value can be calculated in equation (10):

$$G_{ij} = \frac{1}{K}[G_{ij}^1 + G_{ij}^2 + ... + G_{ij}^K] \quad (10)$$

where $G_{ij}^K (i = 1,2,...,m; j = 1,2,...,n)$ is the attribute rating value of Kth DMs and can be described by the grey number $G_{ij}^K = [\underline{G}_{ij}^K, \overline{G}_{ij}^K]$.

Step 3

Construct the grey decision matrix D that the structure of the matrix can be expressed in equation (11):

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

where G_{ij} are linguistic variables based on the grey number.

Step 4

Normalize the grey decision matrix in equation (12): the process is to transform different scales and units among various criteria into common measurable units to allow comparisons across the criteria. 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 in equations (13) and (14).

$$D^* = \begin{bmatrix} G_{11}^* & G_{12}^* & \cdots & G_{1n}^* \\ G_{21}^* & G_{22}^* & \cdots & G_{2n}^* \\ \vdots & \vdots & \ddots & \vdots \\ G_{m1}^* & G_{m2}^* & \cdots & G_{mn}^* \end{bmatrix} \quad (12)$$

where for a benefit attribute G_{ij}^* is expressed as:

$$G_{ij}^* = \left[\frac{\underline{G}_{ij}}{G_j^{max}}, \frac{\overline{G}_{ij}}{G_j^{max}} \right] \quad (13)$$

$$G_j^{max} = \max_{1 \le j \le m} \{\overline{G}_{ij}\}$$

for a cost attribute G_{ij}^* is expressed as:

$$G_{ij}^* = \left[\frac{G_j^{min}}{\overline{G}_{ij}}, \frac{G_j^{min}}{\underline{G}_{ij}} \right] \quad (14)$$

$$G_j^{min} = \min_{1 \le i \le m} \{\underline{G}_{ij}\}$$

The normalization method mentioned above is to preserve the property that the ranges of the normalized grey number belong to [0, 1].

Step 5

Establish the weighted normalized grey decision matrix in equation (15). Considering the different importance of each attribute, the weighted normalized grey decision matrix can be established as

$$D^* = \begin{bmatrix} V_{11} & V_{12} & \cdots & V_{1n} \\ V_{21} & V_{22} & \cdots & V_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ V_{m1} & V_{m2} & \cdots & V_{mn} \end{bmatrix} \quad (15)$$

where $V_{ij} = G_{ij}^* \times W_j$

Step 6

Make the ideal and negative-ideal alternative as a referential alternative for the Grey based model. For m possible supplier alternatives set $S=\{S_1,S_2,...,S_m\}$, the ideal and negative-ideal referential supplier alternative are $S^{max} = \{G_1^{max}, G_2^{max}, ..., G_n^{max}\}$ and $S^{min} = \{G_1^{max}, G_2^{max}, ..., G_n^{max}\}$ respectively, can be obtained in equations (16) and (17) respectively.

$$S^{max} = \{[\max_{1 \le i \le m} \underline{G}_{i1}, \max_{1 \le i \le m} \overline{G}_{i1}], ...[\max_{1 \le i \le m} \underline{G}_{in}, \max_{1 \le i \le m} \overline{G}_{in}]\} \quad (16)$$

$$S^{min} = \{[\min_{1 \le i \le m} \underline{G}_{i1}, \min_{1 \le i \le m} \overline{G}_{i1}], ..., [\min_{1 \le i \le m} \underline{G}_{in}, \min_{1 \le i \le m} \overline{G}_{in}]\} \quad (17)$$

Step 7

Calculate the grey possibility degree between compared supplier alternatives set $S=\{S_1,S_2,...,S_m\}$ and ideal S_{max} referential supplier alternative in equation (18):

$$P_1 = P\{S_i \le S^{max}\} = \frac{1}{n} \sum_{j-1}^{n} P\{V_{ij} \le G_j^{max}\} \quad (18)$$

The smaller one is better [2].

3.2. Combination of the new method with the concept of TOPSIS

To consider both the positive and negative ideal solution to evaluate the suppliers, we proposed the two following steps.

Step 8

Calculate the grey possibility degree between compared suppliers alternatives set $S=\{S_1,S_2,\ldots,S_m\}$ and negative ideal S^{min} referential supplier alternative in equation (19):

$$P_2 = P\{S_i \geq S^{\min}\} = \frac{1}{n}\sum_{j-1}^{n} P\{V_{ij} \geq G_j^{\min}\} \quad (19)$$

The bigger one is better.

Step 9

Find the relative closeness of each alternative to the ideal solution, which is defined in equation (20):

$$C_i = \frac{P_1}{P_2} \quad (20)$$

Step 10

Rank the alternatives. The supplier with minimum C_i is better. According to the above procedures, the ranking order of all suppliers can be determined and we can select the best from among a set of suppliers.

4. Application and analysis

In Li's et al. [2] article, there are six suppliers $S_i(i = 1,2,\ldots,6)$ selected as alternatives against four attributes $Q_j(j=1,2,3,4)$. The four attributes are product quality, service quality, delivery time and price respectively. Q_1, Q_2 and Q_3 are benefit attributes, the greater values being better. Q_4 is cost attributes, the smaller values are better. Here, Li's et al. [2] method and its improvement are described, respectively.

4.1. The new grey based method

The calculation procedures are as follows [2]:

Step 1

Make the weights of attributes Q_1, Q_2, Q_3 and Q_4. 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 equation (9), the evaluation values of attribute weights from four MDs can be obtained and the results are shown in Table 3. The sum of weights must be 1, otherwise we normalized them.

Table 3.
Attribute weights for six suppliers [2]

Q_j	D_1	D_2	D_3	D_4	w_j
Q_1	VH	H	H	H	[0.675, 0.925]
Q_2	H	VH	VH	H	[0.750, 0.950]
Q_3	MH	H	H	MH	[0.550, 0.750]
Q_4	M	M	MH	MH	[0.450, 0.550]

Step 2

Make attribute rating values for six supplier alternatives. According to equation (10), the results of attribute rating values are shown in Table 4.

Table 4.
Attribute rating values for supplier [2]

Q_j	S_i	D_1	D_2	D_3	D_4	G_{ij}
Q_1	S_1	G	MG	G	G	[5.75, 8.25]
	S_2	MG	G	F	MG	[5.00, 6.50]
	S_3	F	F	MG	G	[4.75, 6.25]
	S_4	F	MG	MG	F	[4.50, 5.50]
	S_5	MG	F	F	MG	[4.50, 5.50]
	S_6	G	MG	MG	MG	[5.25, 6.75]
Q_2	S_1	G	G	MG	MG	[5.50, 7.50]
	S_2	G	MG	MG	G	[5.50, 7.50]
	S_3	F	F	P	F	[3.25, 4.50]
	S_4	P	MP	MP	P	[2.00, 3.50]
	S_5	MP	MP	P	MP	[2.50, 3.75]
	S_6	MP	P	P	MP	[2.00, 3.50]
Q_3	S_1	G	MG	MG	G	[5.50, 7.50]
	S_2	MG	G	G	G	[5.75, 8.25]
	S_3	G	G	F	MG	[5.25, 7.25]
	S_4	G	MG	MG	G	[5.50, 7.50]
	S_5	MG	F	F	MG	[4.50, 5.50]
	S_6	F	F	MG	F	[4.25, 5.25]
Q_4	S_1	F	G	G	G	[5.50, 8.00]
	S_2	G	G	F	MG	[5.75, 8.25]
	S_3	VG	VG	G	G	[7.50, 9.50]
	S_4	G	MG	G	G	[5.75, 8.25]
	S_5	MG	MG	G	MG	[5.25, 6.75]
	S_6	G	VG	VG	G	[7.50, 9.50]

Step 3

Establish the grey decision matrix. According to equation (11), we can obtain the grey decision matrix of suppliers.

Step 4

Establish the grey normalized decision table. According to grey normalized decision matrix shown in equation (12), the grey normalized decision table is shown in Table 5.

Table 5.
Grey normalized decision table [2]

S_i	Q_1	Q_2	Q_3	Q_4
S_1	[0.70, 1.00]	[0.73, 1.00]	[0.67, 0.91]	[0.66, 0.96]
S_2	[0.61, 0.79]	[0.73, 1.00]	[0.70, 1.00]	[0.72, 1.00]
S_3	[0.58, 0.76]	[0.43, 0.60]	[0.64, 0.88]	[0.55, 0.70]
S_4	[0.55, 0.67]	[0.27, 0.48]	[0.67, 0.91]	[0.64, 0.91]
S_5	[0.55, 0.67]	[0.33, 0.50]	[0.55, 0.55]	[0.78, 1.00]
S_6	[0.64, 0.82]	[0.27, 0.48]	[0.52, 0.64]	[0.55, 0.70]

Step 5

Establish the grey weighted normalized decision table. According to the grey weighted normalized decision matrix shown in equation (15), the grey weighted normalized decision table is shown in Table 6.

Table 6.
Grey weighted normalized decision table [2]

S_i	Q_1	Q_2	Q_3	Q_4
S_1	[0.47, 0.93]	[0.55, 0.95]	[0.37, 0.68]	[0.30, 0.53]
S_2	[0.41, 0.73]	[0.55, 0.95]	[0.38, 0.75]	[0.33, 0.55]
S_3	[0.39, 0.70]	[0.33, 0.57]	[0.35, 0.66]	[0.25, 0.39]
S_4	[0.37, 0.62]	[0.20, 0.44]	[0.37, 0.68]	[0.29, 0.50]
S_5	[0.37, 0.62]	[0.25, 0.48]	[0.30, 0.50]	[0.35, 0.55]
S_6	[0.43, 0.76]	[0.20, 0.44]	[0.28, 0.48]	[0.25, 0.39]

Step 6

Make the ideal S^{max} and negative ideal S^{min} supplier as a referential alternative. According to equations (16) and (17), the ideal S^{max} and negative ideal S^{min} supplier are shown as follows:

$$S^{\max} = \{[0.470,0.925],[0.550,0.950],[0.383,0.750],[0.350,0.550]\}$$
$$S^{\min} = \{[0.368,0.617],[0.200,0.443],[0.283,0.477],[0.249,0.385]\}$$

Step 7

Calculate the grey possibility degree between compared suppliers alternatives set $S=\{S_1,S_2,...,S_{16}\}$ and ideal referential supplier alternative S^{max}. According to equation (18), the results of the grey possibility degree are shown as follows [2]:

$$P(S_1 \le S^{\max}) = 0.539 \qquad P(S_2 \le S^{\max}) = 0.575$$
$$P(S_3 \le S^{\max}) = 0.789 \qquad P(S_4 \le S^{\max}) = 0.747$$
$$P(S_5 \le S^{\max}) = 0.771 \qquad P(S_6 \le S^{\max}) = 0.840$$

The smaller one is better.

4.2. The combination method

Step 8

Calculate the grey possibility degree between compared suppliers alternatives set $S=\{S_1,S_2,...,S_{16}\}$ and negative ideal referential supplier alternative S_{min}. According to equation (19), the results of the grey possibility degree are shown as follows:

$$P(S_1 \ge S^{\min}) = 0.832 \qquad P(S_2 \ge S^{\min}) = 0.797$$
$$P(S_3 \ge S^{\min}) = 0.649 \qquad P(S_4 \ge S^{\min}) = 0.626$$
$$P(S_5 \ge S^{\min}) = 0.633 \qquad P(S_6 \ge S^{\min}) = 0.544$$

The bigger one is better.

Step 9

Calculate the relative closeness to the ideal supplier. According to equation (20), the results of relative closeness are shown as follows:

$$C_1 = 0.647 \qquad C_2 = 0.722 \qquad C_3 = 1.215$$
$$C_4 = 1.194 \qquad C_5 = 1.218 \qquad C_6 = 1.546$$

Step 10

Rank the order of six suppliers S_i(i=1,2,…,6).

Step 10a

According to Step 7, which is the outcome of the grey based method [2], the result of ranking order is shown as follows: $S_1>S_2>S_4>S_5>S_3>S_6$.

Li et al. [2] stated that, "We can say that the supplier S_1 is the best supplier out of the six. S_1 should be an important alternative for the company. The next important alternative is S_2. Because of the grey possibility, degrees of S_1 and S_2 against the ideal Smax are almost equal. S_4, S_5 and S_3 are good suppliers and S_6 is the worst supplier".

Step 10b

According to Step 9, which is the outcome of the combination of the method with TOPSIS concepts, the result of ranking order is shown as follows: $S_1>S_2>S_4>S_5>S_3>S_6$.

Here the importance of S_3 became more than S_5. Suppliers S_4, S_3 and S_5 are not very good suppliers, because there is considerable difference between C_2 and C_4, moreover S_6 is the worst supplier that is the same as Li's et al. [2] result.

Here, we compare $P(S_i \le S^{max})$ and $P(S_i \ge S^{min})$ for all suppliers with Fig. 2. First we need to normalize the two grey possibility degrees to allow this comparison which are shown in Table 7.

Table 7.
Normalized $P(S_i \le S^{max})$ and $P(S_i \ge S^{min})$

S_i	P ($S_i \le S^{max}$)	N P ($S_i \le S^{max}$)	P ($S_i \ge S^{min}$)	N P ($S_i \ge S^{min}$)
S_1	0.539	0.126	0.832	0.204
S_2	0.575	0.135	0.797	0.195
S_3	0.789	0.185	0.649	0.159
S_4	0.747	0.175	0.626	0.153
S_5	0.771	0.181	0.633	0.155
S_6	0.840	0.197	0.544	0.133
Sum	4.261	1.000	4.081	1.000

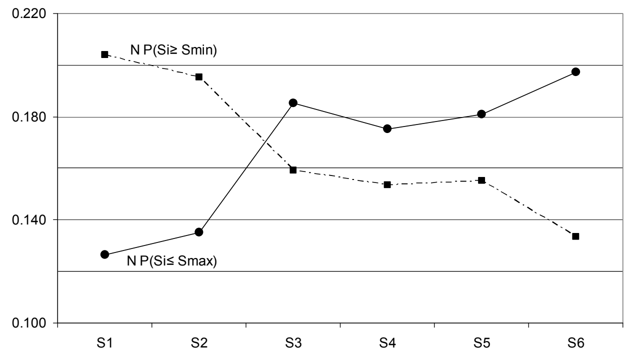

Fig. 2. Comparison of $P(S_i \le S^{max})$ and $P(S_i \ge S^{min})$ for The Six Suppliers

Fig. 2 shows that suppliers 1 and 2 are near to PIS and also far from NIS, which considering the effect of the synergy generated by the two distances, it causes these two suppliers become more important for the buyer. In contrast supplier 6 becomes less important and the other three suppliers remain almost the same.

This synergy can be taken into account by equation (20). The results of equation (20) are compared with equation (20), which is Li's et al. [2] method outcomes, in Fig. 3 for all suppliers. Table 8 is prepared similar to Table 7 that is used to construct Fig. 3.

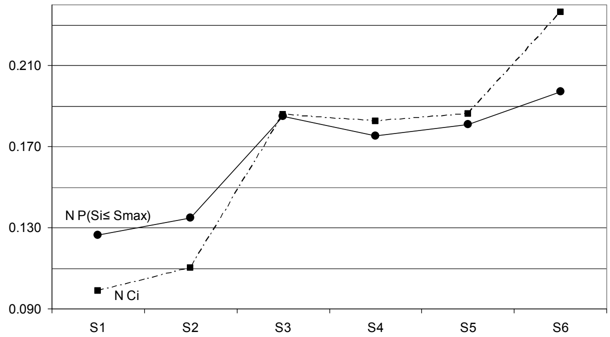

Fig. 3. Comparison of $P(S_i \leq S^{max})$ and C_i for The Six Suppliers

Fig. 3 shows that the importance of suppliers 1 and 2 increased for the buyer by considering both PIS and NIS for evaluating the suppliers and supplier 6 became worse. On the other hand, it cannot be concluded that S_4, S_5 and S_3 are good suppliers, because the distance between them and S_1, S_2 is rather considerable. By the illustration, it is clear that without consideration of NIS to evaluate and choose the best supplier, we can not have an exact solution.

Table 8.
Normalized $P(S_i \leq S^{max})$ and C_i

S_i	N $P(S_i \leq S^{max})$	N C_i
S_1	0.126	0.099
S_2	0.135	0.110
S_3	0.185	0.186
S_4	0.175	0.183
S_5	0.181	0.186
S_6	0.197	0.236

The difference in relative closeness C_i between the suppliers will be important when management wants to split order quantities among the suppliers. At that time the final score of each supplier is used as coefficients of an objective function in linear programming to assign order quantities to the suppliers.

5. Conclusions

Supplier selection is a MADM problem that in conventional MADM methods, the ratings and the weights of attributes must be known precisely [2,17]. As Li et al. [2] declared, in many situations DMs' judgments are often uncertain and cannot be estimated by an exact numerical value. Thus, supplier selection problem has many uncertainties and becomes more difficult. Grey theory is a new mathematical field that is one of the methods used to study the uncertainty of a system. Moreover, the advantage of grey theory over fuzzy sets theory [16] is that grey theory can deal flexibly with both the fuzziness situation and incomplete information [2].

In this paper, we proposed to combine the new grey based approach [2] with the concept of TOPSIS to deal with the supplier selection problem in an uncertain environment. The same as Li's et al. [2] article, the ratings of attributes are described by linguistic variables that can be expressed in grey numbers. A grey possibility degree was also used to compare the ranking of grey numbers and select the most desirable supplier [2]. Through this article, it was demonstrated that the improved method, which is used to solve the MADM problems for selecting the best supplier, is a good means of evaluation, and it appears to be more appropriate.

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