Multi Criteria Supplier Selection Using Fuzzy PROMETHEE Method

Ozlem Senvar, Gülfem Tuzkaya and Cengiz Kahraman

Abstract The fundamental objective of supply chain management (SCM) is to integrate various suppliers to satisfy market demand. Supplier evaluation and selection is very important for establishing an effective supply chain. As a matter of fact, supplier selection consists of both qualitative and quantitative criteria, so it is considered as a multi criteria decision making (MCDM) problem. Under incomplete or uncertain information, the fuzzy set theory allows us make decisions with approximate reasoning. In order to overcome the uncertainty which is constituted by vague situations in supplier selection, we utilize the "extension of the PROMETHEE method in a fuzzy environment" (F-PROMETHEE). In this chapter, multi criteria supplier selection based on a fuzzy PROMETHEE method with an application to supplier selection decision problem is conducted. The main advantages of the methodology are the user friendliness coming from the linguistic evaluations, and the consideration of the vagueness or fuzziness inherent to the decision making environment. Hence, the method can be an efficient and effective methodology to be used by decision makers on supply chains. The proposed methodology can also be applied to any other selection problem.

Keywords Supply chain management (SCM) · Supplier selection · Multiple criteria decision making (MCDM) · Preference ranking organization METHod for enrichment evaluations (PROMETHEE) · Fuzzy logic

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1 Introduction

Variation in demands for production enforces outsourcing of activities. Primary problem in supply chain is control and coordinate activities (Nazeri et al. 2011). Supply Chain Management (SCM) is a process of organizing the activities from the customer's order through final delivery for speed, efficiency, and quality (Meredith 2007). SCM has an increasing importance in today's competitive business world. Companies need to have strong relationships and integrations with their suppliers for a successful SCM system. They should establish appropriate relationships with their suppliers in order to achieve their strategic goals. Therefore, supplier selection is a fundamental step of supply chain management.

Supplier evaluation process allows the selection of suitable suppliers in order to develop a supply relationship system that can rapidly react to requirements of market and to innovation dynamics (Esposito and Passaro 2009a, 2009b). Choosing an appropriate supplier considerably reduces cost, causes to competitive advantage and increases the level of customer satisfaction (Nazeri et al. 2011). Moreover, supplier selection has strategic importance in global competition for companies.

The supplier selection problem consists of the definition of models and methods to analyze and measure the performance of a set of suppliers, which are also known as vendors, in order to improve competitiveness. Supplier selection problem is a multiple criteria decision making (MCDM) problem typically having conflicting criteria that include both qualitative and quantitative measures.

Bruno et al. (2012) provided the perspective analysis of the articles about the supplier selection problem with respect to the geographic origin. Considering the country where the institution of the first author is based, they realized that USA is the main contributor to the literature with 49 articles, followed by Taiwan with 36 articles, Turkey with 27 articles, China with 21 articles, India with 16 articles, and Iran with 14 articles. This evidence testifies that the supplier selection problem is a relevant issue involving academics and practitioners of several countries, more specifically the Asian ones, where manufacturing is the prominent economic activity and/or is based on the attraction of investment by large foreign companies.

Ha and Krishnan (2008) classified researches as single models and combined models. Single models cover Mathematics, Statistics, and Artificial Intelligence.

- *Mathematics* includes multi criteria decision making methods such as analytic hierarchy process (AHP), analytic network process (ANP), analytic target cascading (ATC), game theory, data envelopment analysis (DEA), costing, and grey maths.
- *Statistics* includes process capability index (PCI), factor analysis, multivariate statistics, bootstrap, data mining, structural equations, loss functions, survey, and decision trees.
- *Artificial Intelligence* includes fuzzy set theory, simulation, expert systems, case based reasoning (CBR), vector machines, and neural networks.

Combined models cover Mathematics combined models, Artificial Intelligence combined models, Hybrid combined models.

- *Mathematics* combined models include AHP-ANP-Optimization, AHP-ANP + DEA, AHP-ANP + Grey Maths, DEA + Optimization, and DEA + Costing.
- *Artificial Intelligence* combined models include case based reasoning (CBR) + neural networks.
- *Hybrid combined models* include AHP-ANP + fuzzy set theory, AHP-ANP + simulation, AHP-ANP + loss function, AHP-ANP + quality function, costing + fuzzy set theory, DEA + neural networks, neural networks + optimization, fuzzy set theory + cluster analysis, fuzzy set theory + optimization, and simulation + optimization.

Up to now, there are many other investigations and many other publications about supplier selection have been issued. The contribution of this chapter is to utilize a method for multi criteria supplier selection problem based on fuzzy PROMETHEE which overcomes the uncertainty constituted by vague situations. Therefore, in this chapter, the "extension of the PROMETHEE method in a fuzzy environment" (F-PROMETHEE) is used for supplier selection problem. The main advantages of the methodology are user friendliness coming from the linguistic evaluations, and the consideration of the vagueness or fuzziness inherent to the decision making environment. Additionally, the utilized technique, which is known as a fuzzy version of well-known PROMETHEE outranking methodology, sustains the advantages of PROMETHEE. One of the main advantages of PROMETHEE is the simplicity of its methodology in comparison to the other outranking techniques. This is the main reason why this technique is applied to various real life problems previously. Also, PROMETHEE provides the opportunity of selection the types of preference functions. This characteristic is unique to the PROMETHEE approach and gives the opportunity of obtaining more realistic definition for the decision criteria. Hence, the method can be an efficient and effective methodology to be used by decision makers on supply chains. Although it is not very common, some versions of fuzzy PROMETHEE are applied to the supplier selection problem previously. Chen et al. (2011) used fuzzy PROMETHEE for the outsoursing decisions of Information Systems. Shirinfar and Haleh (2011) used fuzzy PROMETHEE for the supplier selection and evaluation problem. Gupta et al. (2012) used fuzzy PROMETHEE to select logistics service providers for cement industry. Tavakoli et al. (2013) applied fuzzy PROMETHEE in an fuzzy Goal Programming integrated methodology to evaluate and select suppliers. In this study, we used SCOR Level 1 performance metrics as evaluation criteria for suppliers and applied the proposed methodology to a hypothetical example.

To the best of our knowledge, in the literature, other studies using F-PROMETHEE approach can be summarized as follows. Goumas and Lygerou (2000), Bilsel et al. (2006), Geldermann et al.(2000), Chou et al. (2007), Tuzkaya et al. (2010), and Ozgen et al. (2011) have used F-PROMETHEE previously.

The organization of the rest of this chapter is as follows. Section 2 provides a brief literature review for supplier selection problem. Section 3 presents background information of PROMETHEE method and Sect. 4 gives brief information on fuzzy PROMETHEE approach. Section 5 is the application section and in the final section some concluding remarks and future research directions are given.

2 Supplier Selection Problem

Due to strategic importance of supplier selection process, extensive research has been done on supplier evaluation and selection. Particularly, more recent researches reveal that the interest devoted to this topic is increasing. In this section, a brief literature review about supplier selection problem is provided.

According to Nazeri et al. (2011) supplier selection is one of the most significant processes of product and service management for many enterprises within supply chain. Especially, in manufacturing companies the raw materials and component parts can equal up to 70 % of the product cost. In such circumstances the purchasing unit can affect in cost reduction. Supplier evaluation is one of the most fundamental issues of purchasing management. They also emphasize that the process of supplier selection and evaluation is MCDM, that is, in supplier selection many criteria may be considered during this process. Therefore, supplier selection and evaluation is a MCDM problem which includes both tangible and intangible criteria, some of which may conflict. Fundamentally, supplier selection and evaluation can be divided into two categories, which are single sourcing and multiple sourcing. In single sourcing, there are constraints, which are not considered in the supplier selection process. In other words, all suppliers can satisfy the buyer's requirements of demand, quality, delivery, and etc. The buyer only needs to make one decision, which supplier is the best. On the other hand, in multiple sourcing, there are some limitations such as supplier's capacity, quality, and delivery, which are considered in the supplier selection process. In other words, no supplier can fulfill the buyer's total requirements and the buyer needs to purchase some part of demand from one supplier and the other part of the demand from another supplier to compensate for the shortage of capacity or low quality of the first supplier. In these circumstances, buyers need to make two decisions: which suppliers are the best, and how much should be purchased from each selected supplier?

Traditional supplier evaluation and selection methods focus on the requirements of single enterprises, and fail to consider the entire supply chain. Managing the links between the suppliers and customers successfully in a supply chain necessitates their active collaboration. As a result, companies prefer to work closely with a few suppliers or dependable one supplier in order to achieve and maintain high supply chain performance. Due to strategic importance of supplier evaluation and selection process, extensive research is being done to cope with this MCDM problem. In recent years there has been a great focus on the mathematical side of the supplier selection problem. Mathematical methodologies trying to answer to the complexity of the problem, intrinsically multi-attributed.

Agarwal et al. (2011) review sixty-eight articles from 2000 to 2011 to find out the most prominent MCDM methodology followed by the researchers for supplier evaluation and selection. They report the distribution of MCDM methods used in these articles as follows: Data Envelopment Analysis (DEA): 30 %; mathematical programming models: 17 %; Analytic Hierarchy Process (AHP): 15 %; Case Based Reasoning (CBR): 11 %; Analytic Network Process (ANP): 5 %; Fuzzy Set Theory: 10 %; Simple Multi-Attribute Rating Technique (SMART): 3 %; Genetic Algorithm (GA): 2 %; and Criteria Based Decision Making Methods such as ELECTRE (ELimination Et Choix Traduisant la REalité-Elimination and choice expressing reality) and PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations): 7 %.

De Boer et al. (2001) present a review of decision methods reported in the literature for supporting the supplier selection process. They define pre-qualification as the process of reducing the set of all suppliers to a smaller set of acceptable suppliers and present categorical methods, DEA, cluster analysis, and CBR systems as the decision methods for pre-qualification of suitable suppliers. They present linear weighting models, total cost of ownership models, mathematical programming models, statistical models, and artificial intelligence-based models as the decision models for making a final choice among suitable suppliers.

Ha and Krishnan (2008) provide a classification of the employed approaches for dealing with the supplier selection problem. They also show price, quality and delivery are the three most used attributes.

Based on a literature review of 78 journal articles from 2000 to 2008 on MCDM approaches for supplier evaluation and selection, Ho et al. (2010) conclude that the most prevalent individual approach is DEA, whereas the most popular integrated approach is AHP−GP (Goal Programming); the integrated AHP approaches with other techniques include bi-negotiation, DEA, DEA and artificial neural network, GP, grey relational analysis, mixed integer non-linear programming, multi-objective programming, and fuzzy set theory. They also conclude that the most popular criterion used for evaluating the performance of suppliers is quality, followed by delivery, price/cost, manufacturing capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, and safety and environment.

Chen (2011) summarizes important criteria for supplier selection from the literature as price, delivery, quality, equipment and capability, geographic location, technical capability, management and organization, industrial reputation, financial situation, historical performance, maintenance service, service attitude, packing ability, production control ability, training ability, procedure legality, employment relations, communication system, mutual negotiation, previous image, business relations, previous sales, guarantee and compensation. Chen (2011) uses DEA technique to screen potential suppliers and then TOPSIS method to rank the candidate suppliers.

For supplier selection problem various researchers have studied different MCDM approaches. AHP is one of the most prominent methodologies used to address the supplier selection problem (Saaty 1980, 1994).

Although, AHP is widely used in many MCDM problems, in the conventional AHP there are some shortcomings (Ayag and Ozdemir 2006a, b);

1. the AHP method is mainly used in nearly crisp decision applications,
2. the AHP method creates and deals with a very unbalanced scale of judgement,
3. the AHP method does not take into account the uncertainty associated with the mapping of one's judgment to a number,
4. ranking of the AHP method is rather imprecise,
5. the subjective judgment, selection and preference of decision-makers have great influence on the AHP results.

In real life applications, human assessment on the relative importance of individual customer requirements is always subjective and imprecise. The linguistic terms that people use to express their feelings or judgments are generally vague. Even though the scale has the advantages of simplicity and ease of use, it does not take into account the uncertainty associated with the mapping of one's perception (or judgment) to a number (Büyüközkan et al. 2004).

Based on an extensive literature survey, the most widely preferred methodology is the combination of AHP with other methodologies, that is, different integrated AHP approaches are observed to be the most widely used. Bruno et al. (2012) conclude that AHP-based models are useful in constructing structured and formalized approaches for supplier evaluation and can be used in combination with many other approaches. For instance, AHP, and its network-based counterpart, ANP (Saaty 1980) are found to be the most utilized methods. The use of AHP/ANP with fuzzy set theory is widely accepted for dealing with qualitative evaluation attributes.

Chen et al. (2006) use the fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method for supplier selection problem.

In this study, the F-PROMETHEE technique is preferred because of the fuzzy nature of the supplier selection decision problem. In the next consecutive sections, PROMETHEE and F-PROMETHEE are explained.

3 PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations)

PROMETHEE is the abbreviation of Preference Ranking Organization METHod for Enrichment Evaluations, which is an outranking method that initial references are prepared by Brans et al. (1984, 1986); Brans and Vincle (1985).

In PROMETHEE method, different preference functions can be defined for criteria (Dagdeviren 2008). It is a ranking method which is quite simple in conception and application compared to other methods for MCDM. It is well adapted to the problems where a finite set of alternatives are to be ranked according to several, sometimes conflicting criteria (Bilsel et al. 2006; Albadvi et al. 2007; Tuzkaya et al. 2010).

Ulengin et al. (2001) listed the advantages of PROMETHEE as follows:

1. PROMETHEE is a user friendly outranking method,
2. It has been successfully applied to real life planning problems
3. Both PROMETHEE I and PROMETHEE II allow both partial and total ranking of the alternatives while still satisfying simplicity.

The evaluation is the starting point of PROMETHEE method. In this phase, alternatives are evaluated with respect to different criteria. These evaluations involve essentially numerical data. Macharis et al. (2004) stated that the implementation of PROMETHEE requires two additional types of information, which are as follows:

- Information on the relative importance (i.e. the weights) of the criteria considered,
- Information on the decision-makers' preference function, which he/she uses when comparing the contribution of the alternatives in terms of each separate criterion.

The basic steps of the PROMETHEE algorithm can be outlined as follows (Geldermann et al. 2000; Brans et al. 1986):

Step 1. Spesify a generalized preference function $p_j(d)$ for each criterion j.

Step 2. Define a vector containing the weights, which are a measure for the relative importance of each criterion, $w_T = [w_1,\ldots,w_k]$. If all the criteria are of the same importance in the opinion of the decision maker, all weights can be taken as being equal. The normalization of the weights, $\sum_{k=1}^{K} w_k = 1$, is not necessarily required.

Step 3. Define for all the alternatives $a_t,\ a_{t'}\ \in A$ the outranking relation π:

$$\pi : \begin{cases} A \times A \rightarrow [0,\ 1] \\ \pi(a_t, a_{t'}) = \sum_{k=1}^{K} w_k\ .(p_k(f_k(a_t) - f_k(a_{t'})) \end{cases} \tag{1}$$

The preference index $\pi(a_t, a_{t'})$ is a measure for the intensity of preference of the decision maker for an alternative at in comparison with an alternative $a_{t'}$ for the simultaneous consideration of all criteria. It is basically a weighted average of the preference functions $p_k(d)$ and can be represented as a valued outranking graph.

Step 4. As a measure for the strength of alternatives $a_t \in A$, the leaving flow is calculated:

$$\Phi^+(a_t) = \frac{1}{T-1} \cdot \sum_{\substack{t'=1 \\ t' \neq t}}^{n} \pi(a_t,\ a_{t'}) \tag{2}$$

The leaving flow is the sum of the values of the arcs which leave node at and therefore yields a measure of the "outranking character" of at.

Step 5. As a measure for the weakness of the alternatives $a_t \in A$, the entering flow is calculated, measuring the "outranked character" of at (analogously to the leaving flow):

$$\Phi^{-}(a_t) = \frac{1}{T-1} \cdot \sum_{\substack{t'=1 \\ t' \neq t}}^{n} \pi(a_{t'}, a_t) \tag{3}$$

Step 6. A graphical evaluation of the outranking relation is derived: Basically, the higher the leaving flow and the lower the entering flow, the better the action. This result is graphically represented by a partial preorder (PROMETHEE I) or a complete preorder (PROMETHEE II).

In PROMETHEE I, alternative at is preferred to alternative at' (atPat') at least one of the elements of Eq. (4) is satisfied (Dagdeviren 2008):

$$\begin{aligned} a_t P a_{t'} \;\; if: \;\; & \Phi^{+}(a_t) > \Phi^{+}(a_{t'}) \; and \; \Phi^{-}(a_t) < \Phi^{-}(a_{t'}) \; or \\ & \Phi^{+}(a_t) > \Phi^{+}(a_{t'}) \; and \; \Phi^{-}(a_t) = \Phi^{-}(a_{t'}) \; or \\ & \Phi^{+}(a_t) = \Phi^{+}(a_{t'}) \; and \; \Phi^{-}(a_t) < \Phi^{-}(a_{t'}) \end{aligned} \tag{4}$$

PROMETHEE I evaluation allows indifference and incomparability situations. Therefore sometimes partial rankings can be obtained. In the indifference situation ($a_t I a_{t'}$), two alternatives a_t and $a_{t'}$ have the same leaving and entering flows (Dagdeviren 2008):

$$a_t I a_{t'} \;\; if: \;\; \Phi^{+}(a_t) = \Phi^{+}(a_{t'}) \; and \; \Phi^{-}(a_t) = \Phi^{-}(a_{t'}) \tag{5}$$

Two alternatives are considered incomparable, $a_t R a_{t'}$, if alternative at is better than alternative $a_{t'}$ in terms of leaving flow, while the entering flows indicate the reverse (Dagdeviren 2008):

$$\begin{aligned} a_t R a_{t'} \;\; if: \;\; & \Phi^{+}(a_t) > \Phi^{+}(a_{t'}) \; and \; \Phi^{-}(a_t) > \Phi^{-}(a_{t'}) \; or \\ & \Phi^{+}(a_t) < \Phi^{+}(a_{t'}) \; and \; \Phi^{-}(a_t) < \Phi^{-}(a_{t'}) \end{aligned} \tag{6}$$

Via PROMETHE II, the complete ranking can be obtained. For the complete ranking calculations, net flow values of alternatives can be calculated as Eq. (7). Here, if alternative a_t's net flow is bigger that alternative $a_{t'}$'s net flow, this indicates that, alternative at outranks alternative at'.

$$\Phi^{net}(a_t) = \Phi^{+}(a_t) - \Phi^{-}(a_t) \tag{7}$$

Note that, the preference function types mentioned in Step 1 is not given in that study. Details of them can be seen in Tuzkaya et al. (2010) and Ozgen et al. (2011).

4 Fuzzy PROMETHEE (F-PROMETHEE)

In the literature, there are a few studies with respect to the fuzzy PROMETHEE (F-PROMETHEE) approach. Goumas and Lygerou (2000), Bilsel et al. (2006), Geldermann et al.(2000), Chou et al. (2007), Tuzkaya et al. (2010), and Ozgen et al. (2011) have used F-PROMETHEE previously.

In the F-PROMETHEE, the main problem arises in comparing two fuzzy numbers and the index, which corresponds to a weighted average of the fuzzy numbers, proposed from Yager (1981) is found a useful way to compare fuzzy numbers. It is determined by the center of weight of the surface representing its membership function (Goumas and Lygerou 2000; Bilsel et al. 2006). Based on the Yager's index, a triangular fuzzy number's magnitude is the value corresponding to the center of the triangle and can be expressed as in Eq. (8). The representation of a TFN here, $\tilde{F} = (n, a, b)$, is a different version of the representation used in Fig. 1 and Table 1. This is equivalent to the previous representation by $\tilde{F} = (n - a, n, n + b)$. The following fuzzy PROMETHEE formulas are based on the representation of TFN as (n, a, b).

$$\tilde{F} = (n - a, n, n + b) = (3n - a + b)/3 \tag{8}$$

In this study, PROMETHEE's linear preference function with indifference and strict preference is preferred for each criterion by (Decision Maker Team) DMT. In this preference function, two thresholds, q and p are needed to be determined. When using the fuzzy numbers in PROMETHEE, the evaluation function can be converted to Eq. (9). As mentioned in the Sect. 3, details of preference functions can be seen in Tuzkaya et al. (2010) and Ozgen et al. (2011).

$$P_j(a_t, a_{t'}) = \begin{cases} 0, & \text{if } n - a \leq q \text{ (indifference)} \\ \frac{(n,a,b)-q}{p-q}, & \text{if } q \leq (n-a) \text{ and } (n+b) \leq p \\ 1, & \text{if } n + b > p \text{ (strict preference)} \end{cases} \tag{9}$$

In Eq. (9), q and p values are crisp numbers and the membership functions of the fuzzy number, $C(a_t, a_{t'}) = (n,a,b)$, is adjusted accordingly so that $n - a >= 0$ and $n + b <= 1$. In the if-statement in Eq. (9), (n,a,b) is a TFN which represents the differences between a_t and $a_{t'}$. The magnitude of (n,a,b) is calculated by using Yager Index (Eq. 8).

Similarly to the PROMETHEE approach, the leaving flow, the entering flow and the net flow notions are valid in the case of F-PROMETHEE (Bilsel et al. 2006). Outside of the abovementioned differences, F-PROMETHEE utilizes from the PROMETHEE's application steps.

In the F-PROMETHEE phase, the DMT is asked to evaluate alternatives considering each criterion. For this evaluation stage, the used linguistic scale for relative importance is given in Fig. 1 and the definitions are given in Table 1.

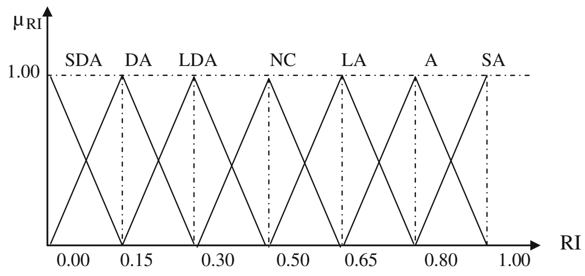

Fig. 1 Linguistic scale for evaluation (Bilsel et al. 2006)

Table 1 Linguistic scale for importance (Bilsel et al. 2006)

Linguistic scale for evaluation	Triangular fuzzy scale
Strongly disagree (SDA)	(0, 0, 0.15)
Disagree (DA)	(0, 0.15, 0.30)
Little disagree (LDA)	(0.15, 0.30, 0.50)
No comment (NC)	(0.30, 0.50, 0.65)
Little agree (LA)	(0.50, 0.65, 0.80)
Agree (A)	(0.65, 0.80, 1)
Strongly agree (SA)	(0.80, 1, 1)

5 An Application

In this study, a hypothetical example for supplier evaluation problem is performed. SCOR Level 1 performance metrics are utilized as the evaluation criteria (Supply Chain Operations Reference (SCOR) Model, Overview-Version 10.0 2013) which is presented as follows: *Reliability* (C_1), *Responsiveness* (C_2), *Agility* (C_3), *Costs* (C_4), *Assets* (C_5). For this application, a weight of each criterion is assumed to be equal and 0.20 each. Also, types of the criteria are determined as level criteria type. The values of q and p are determines as 0 and 0.6, respectively.

Four suppliers (S_1, S_2, S_3, S_4) are evaluated using the determined evaluation criteria. Table 2 shows the supplier evaluations for each criterion. For the evaluation process, linguistic preferences given in Table 1 is used.

Then the linguistic supplier evaluations are converted to triangular fuzzy numbers using the scale given in Table 1 and presented as in Table 3.

Then using the criteria evaluations in Table 3, respective Yager Index values are calculated with Eq. (8). Then Eqs. (4–6) are used to obtain preference, strict preference and indifference relations between each pair of suppliers and Table 4 is obtained with the respective positive, negative and net flow values of suppliers. Net flow values are calculated using Eq. (7).

Since "positive flow value of S_2 is greater than positive flow value of S_1" and "negative flow value of S_2 is smaller than the negative flow value of S_1", it can be concluded that S_2 outranks S_1. Similar, analyses are realized for all other suppliers. As a result, considering the PROMETHEE I outranking conditions, S_3 outranks S_2

Table 2 Supplier evaluation results for SCOR level 1 performance metrics

	C_1	C_2	C_3	C_4	C_5
S_1	DA	SDA	LDA	DA	NC
S_2	LA	NC	LDA	LDA	NC
S_3	NC	LA	NC	A	A
S_4	SA	SA	LA	A	LA

Table 3 Supplier evaluations using triangular fuzzy numbers

	C_1			C_2			C_3		
S_1	0.00	0.15	0.30	0.00	0.00	0.15	0.15	0.30	0.50
S_2	0.50	0.65	0.80	0.30	0.50	0.65	0.15	0.30	0.50
S_3	0.30	0.50	0.65	0.50	0.65	0.80	0.30	0.50	0.65
S_4	0.80	1.00	1.00	0.80	1.00	1.00	0.50	0.65	0.80
	C_4			C_5					
S_1	0.00	0.15	0.30	0.30	0.50	0.65			
S_2	0.15	0.30	0.50	0.30	0.50	0.65			
S_3	0.65	0.80	1.00	0.65	0.80	1.00			
S_4	0.65	0.80	1.00	0.50	0.65	0.80			

Table 4 Negative, positive and net flow values of suppliers

	S_1	S_2	S_3	S_4	Q^+	Q^{net}
S_1	0.00	0.00	0.00	0.00	0.00	−1.60
S_2	0.40	0.00	0.00	0.00	0.40	−0.20
S_3	0.60	0.20	0.00	0.00	0.80	0.40
S_4	0.60	0.40	0.40	0.00	1.40	1.40
Q−	1.60	0.60	0.40	0.00		

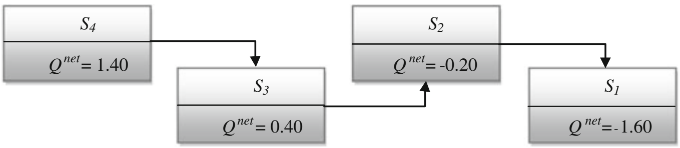

Fig. 2 PROMETHEE II complete ranking results

and S_1, S_4 outranks S_3, S_2 and S_1. There are no indifference relations between any pair of suppliers. PROMETHEE II calculations give same result as can be expected. Net flow values of suppliers shows that S_4 outranks S_3, S_3 outranks S_2, S_2 outranks S_1. Figure 2 illustrates the results of PROMETHEE II which gives the complete rankings.

6 Conclusion

In order to enhance quality and competitiveness levels, outsourcing is inevitable. Selection of the appropriate suppliers is a critical success factor for any outsourcing decision. Traditional supplier evaluation and selection methods focus on the requirements of single enterprises, and fail to consider the entire supply chain. Managing the links between the suppliers and customers successfully in a supply chain necessitates their active collaboration. As a result, companies prefer to work closely with a few suppliers or dependable one supplier in order to achieve and maintain high supply chain performance. Due to strategic importance of supplier evaluation and selection process, extensive research has been made to cope with this MCDM problem.

This study uses a fuzzy PROMETHEE method for a supplier selection problem. The objective is to select the most suitable supplier. The main advantages of the methodology are the user friendliness coming from the linguistic evaluations, and the consideration of the vagueness or fuzziness inherent to the decision making environment. Hence, the method can be an efficient and effective methodology to be used by decision makers on supply chains. The proposed methodology can also be applied to any other selection problem.

For the future researches the proposed methodology can also be easily implemented to other types of selection problems in the other application areas, more specifically in manufacturing and service sectors.

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