Selecting Suppliers Considering Features of 2nd Layer Suppliers by Utilizing FANP Procedure

Mohammad Najafi Nobar (Corresponding author)
Mechanical and Industrial Engineering Faculty, Khajeh Nasir Toosi University of Technology
No17, Pardis St, Mollasadra St, Vanak Sq, Tehran, Iran
Tel: 98-912-320-2283 E-mail: mnajafi@sina.kntu.ac.ir, mohammad.najafi.nobar@gmail.com

Mostafa Setak
Mechanical and Industrial Engineering Faculty, Khajeh Nasir Toosi University of Technology
No17, Pardis St, Mollasadra St, Vanak Sq, Tehran, Iran
Tel: 98-912-304-6513 E-mail: setak@kntu.ac.ir

Alireza Fallah Tafti
Department of Engineering, Shahed University, Khalij Fars Highway, Tehran, Iran
Tel: 98-912-405-8592 E-mail: fallah.ie@gmail.com

Abstract

Nowadays, Supply Chain Management (SCM) is a vital issue which companies are forced to deal with. Considering SCM processes, supplier selection is playing a leading role and the affection of supplied raw materials and assembled parts on end users satisfaction cannot be denied as it can influence over both tangible factors such as financial or quality indicators and intangible ones such as the shared knowledge. The main aim of the presented paper is to highlight the importance of the features of second layer suppliers which have been overlooked in supplier selection process. Therefore a new conceptual supplier selection model is developed to select preferred supplier based on two layers or more. The model is solved using Fuzzy Analytic Network Process (FANP) method which is redesigned using a matrix manipulated and has been fed with real data and the results represent that features of second layer suppliers are as important as first layers'.

Keywords: Supply Chain Management (SCM), Multi Criteria Decision Making (MCDM), Supplier selection, Fuzzy Analytic Network Process (FANP)

1. Introduction and literature review

Nowadays, competitive business environment has forced companies to satisfy customers who demand for more variety of products, lower cost, better quality and faster response (Vendrembse et al, 2006). In each manufacturing process, the decision maker faces with a high number of parameters which affect the final cost of the product. To diminish the cost, the decision maker should do a trade-off among different parameters and then the decision maker would learn about those parameters that play remarkable role in increasing the cost of production. Price of raw materials and component parts is one of the most important parameters which comprise the bulk of the product cost, reaching up to 70% in some cases in most industries (Ghobadian et al, 1993). So when the cost of raw materials or component parts dominates the product cost, supplier selection becomes a crucial process for the company to maintain or lower the cost while holding the quality of the products (Wu et al, 2009).

There can be found so many papers which have considered supplier selection as an important Multi Criteria Decision Making (MCDM) problem in supply chain management which contains tangible and intangible factors. If process is done correctly, a higher quality and longer lasting relationship will be more attainable (Lee, 2009). In other word, selection of wrong supplier could be enough to upset the company's financial and operational position, whereas selecting the right suppliers significantly reduces purchasing cost, improves competitiveness in market and enhances end user satisfaction (Önüt et al, 2009). Supplier selection is a fundamental issue in supply chain and heavily contributes to the overall supply chain performance. In previous decades, supplier selection problem has been noticed as an important problem in both industry and science. First related papers in supplier selection can be traced back to the 1950s when applications of linear programming and scientific computations were at their beginning. The first recorded supplier selection model is that used by the National Bureau of Standards in the United States of America to find the minimum cost way for awarding procurement contracts in the Department of Defense (Aissaoui N et al, 2006). Many articles have discussed both the importance of supplier selection process and the considered criteria used in that process. The oldest one was the study provided by Dickson (1966) which identified quality, delivery and performance history out of 23 criteria as the important ones (Dickson, 1966). Recently Guner (2009) summarized the usage of different supplier selection criteria in 10 articles since 1966 up to 2008 and mentioned that some of criteria such as price, quality, delivery and reputation in industry are wildly used in articles (Guner et al, 2009). In 2001 a review was published by Deboer, Labro and Morlacchi focused on methods supporting supplier selection (De boer L et al, 2001), in 2007 a comprehensive review on supplier selection and order lot sizing methods was done by Aissaoui and her colleagues (Aissaoui N et al, 2007) and the latest review on supplier selection was performed by William, Xiaowei and Parsanta. They reviewed multi criteria decision making approaches for supplier evaluation and selection process (William HO et al, 2010).

There are so many papers which have presented various methods and procedures. Most of them are MCDM methods such as mathematical programming (MP), goal programming (GP), heuristic algorithms such as genetic algorithm (GA), etc, with the aim of simplifying the process with more accuracy and also seeking some other objectives such as the order quantity, capacity, etc. the mathematical programming (MP) includes linear programming (LP) and combination linear programming. Goal programming (GP) has been studied and applied in supplier selection by so many researchers such as Muralidharan et al (2002), Weber et al (1998), Lee (2009).

The AHP method introduced by Saaty, has many applications in supplier selection process since many researchers have utilized it and its derivatives like Fuzzy Analytic Hierarchy Process (FAHP) and Analytic Network Process (ANP) in their articles. As William mentioned in his article, AHP and ANP have been applied in ten articles from 78 (about 13 percent) international journal articles which were reviewed (William HO et al, 2010). As an instance, Kokangul et al (2008) utilized AHP with non linear programming and, also, multi objective programming to create a procedure for selecting supplier which contains such parameters like capacity, discount, etc.

In our survey about different methods of supplier selection, we could find no article which evaluates the supplier from the second layer supplier's point of view. In presented article, align with considering the aforementioned view point, the FANP has been applied. The other sections of this paper are as following:

The proposed conceptual model of selecting suppliers considering features of the second layer suppliers is introduced in section 2. Section 3 is a review of two methods which are very common in MCDM, Classic ANP, Fuzzy ANP and Chengs' extent analysis method. Introduction of proposed FANP for supplier selection is mentioned in section 4. Applying the aforementioned model to one of the examples from Industry and analyzing results attained is presented in section 5 and finally, conclusion is discussed in section 6.

2. Proposed conceptual model of selecting suppliers considering 2nd layer suppliers' features

Firstly, it is considered that there exists an industrial unit with the aim of manufacturing final products and distribute directly to market and deliver to end users. Therefore the main manufacturer assembles some parts and components parts to make a final product. Assuming that the main manufacturer requires N parts, N can be separated into two groups. The first refers to those parts which are standard and manufactured in large amounts such as screws and are directly used in production line. The second group represents those parts which the production volume might not be the same for different products (such as brake pads and gearboxes in different vehicles) and the main focus of this article is on this kind of parts. Let n be a subset of N that contains number of parts which are belonged to second group, then P_i demonstrated the i^{th} part of n; so the main manufacturer require at least n different supplier in order to run production lines. Considering that the number of suppliers for different parts can be unequal, so the main manufacturer may face with so many suppliers. Let presume that the main manufacturer is in contact with m supplier for supplying each part, and then S_{ij} shows the j^{th} supplier of i^{th} part. It is obvious that each part of n parts requires k raw materials in order to be produced at the first layer supplier's plants (R is used to represent raw materials) which each of the raw material has its own suppliers (2nd layer).

As an instance, assume that the main manufacturer produces passenger cars as its final products, so it requires brake pads (as one of the required parts) and there are numerous suppliers which supply and manufacture it (1st layer of suppliers). Since 11 raw materials such as metal, aluminium oxide are needed, so R_{li} represents the l^{th}

raw material for the i^{th} part. Each raw material has different sources to be supplied and suppliers in first layer ought to be connected to aforementioned sources in order to manufacture the products. Consider that each of K raw materials, which have a definite role in production, has h suppliers in second layer, so Pr_{tli} explains the t^{th} supplier of l^{th} raw material for the i^{th} part. In order to better understanding this concept, a figure is provided which depicted the sequence of 1^{st} and 2^{nd} layer of suppliers Fig. 1.

The parameters of the Fig. 1. are as follows:

N: number of whole required parts, n: number of required part with two layers of suppliers, N-n: number of required standard parts, P_i: i^{th} required part from n (i=1,2,…,n), S: First layer suppliers, m: number of 1st layer suppliers for each part, S_{ji}: the j^{th} supplier for i^{th} part (j=1,2,…,m), R: required raw material for each part, K: number of required raw material for each part, R_{Li}: the l^{th} raw material which is required for i^{th} part (L=1, 2,…, k), Pr: second layer suppliers, h: number of suppliers for each raw material, Pr_{tLi}: the t^{th} supplier of l^{th} raw material for i^{th} part (t=1,2,…,h)

3. Review on ANP and Fuzzy ANP methods

3.1 Analytic Network Process (ANP)

Analytic hierarchy process (AHP) was proposed by Saaty (1980) as a multiple criteria decision making method and has been used to solve a wide range of problems. The basic assumptions of AHP are that it can be used in functional independence of an upper part or cluster of the hierarchy from all its lower parts and the criteria or items in each level (meade & sarkis, 1999). But the most of decision-making problems cannot be structured hierarchically because they involve the interaction and dependence of higher level elements on lower level elements (saaty & takizawa, 1986; saaty, 1996), and must be built as a network system to allow feedback, dependencies and interrelationships among criteria. For filling this gap and providing a more generalized model, the analytic network process (ANP) extends the AHP as a new analysis method to problems with dependencies and feedback among the criteria and alternatives by using a ‘‘supermatrix’’ approach (saaty, 1996). In an ANP model, the interdependencies within the same level of attributes and among different levels may shows by looped arc and two-way arrow respectively.

The supermatrix is a segmented matrix, where each submatrix is composed of a set of relationships between two components or clusters in a connection network structure. If there is no interdependent relationship among the criteria, the pairwise comparison value would be 0. In contrast, if an interdependent and feedback relationship exists among the criteria, then such value would no longer be 0 and an unweighted supermatrix M will be achieved. If the matrix does not conform to the principle of column stochastic, the decision maker can provide the weights to adjust it into a supermatrix that conforms to the principle of column stochastic, and it will become a weighted supermatrix m. We then get the limited weighted supermatrix M^* based on Eq. (1) and allow for progressive convergence of the interdependent relationship to achieve the precise relative weights among the criteria (Tseng et al., 2008).

$$M^* = \lim_{k \to \infty} M^k \tag{1}$$

3.2 Fuzzy Analytic Network Process (FANP)

Nevertheless, Both AHP and ANP methods deal only with comparison ratios which are crisp but usually, most of parameters are uncertain. To deal with this problem due to vagueness and imprecision, the fuzzy set theory is introduced by Zadeh (1965) and afterwards various authors proposed many fuzzy AHP and FANP methods (Van Laarhoven and Pedrycz, 1983; Buckley, 1985; Chang, 1992, 1996; Cheng, 1997; Deng, 1999; Leung and Cao, 2000; Mikhailov, 2004). These methods are systematic approaches to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis. FANP method gives better illumination and learning in decision-making process. Below main advantages of the FANP against classical ANP are given (Mikhailov and Singh, 2003b)

It better models the ambiguity and imprecision associated with the pairwise comparison process.
It successfully derives priorities from both consistent and inconsistent judgments.
It is cognitively less demanding for the decision makers.
It is an adequate reflection of the decision-makers' attitude toward risk and their degree of confidence in the subjective assessments.
In this study, we use Chang's extent analysis method (Chang et al, 1992, 1996; Kahraman et al, 2006) because the steps of this approach are easier than the other fuzzy AHP approaches.

3.3 Chang's extent analysis method

Let X = {$x_1,x_2,\ldots,x_n$} be an criterion set, and U = {$u_1,u_2,\ldots,u_n$} be a goal set. According to the Chang's extent analysis method, each object is taken and extent analysis for each goal performed respectively. Therefore, m, extent analysis values for each criterion, can be obtained with the following notations (Kahraman, et al, 2004):

$$M_{g_i}^1, M_{g_i}^2, M_{g_i}^3, \ldots, M_{g_i}^m, \; i= 1,2, \ldots, n \quad (2)$$

Where all the $M_{g_i}^j$ (*j=1,2,...,m*) are TFN. The steps of Chang's analysis can be given as in the following:

Step 1: The fuzzy synthetic extent value (S_i) with respect to the i^{th} criterion is defined as:

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \quad (3)$$

To obtain $\sum_{j=1}^{m} M_{g_i}^j$, perform the fuzzy addition operation of *m* extent analysis values for a particular

matrix such that

$$\sum_{j=1}^{m} M_{g_i}^j = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \quad (4)$$

To obtain $[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j]^{-1}$, perform the fuzzy additional operation of $M_{g_i}^j$ (j=1, 2, …, m) values such

That

$$[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j] = (\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i) \quad (5)$$

and then compute the inverse of the vector in Eq. (6) such that

$$[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j]^{-1} = (\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}) \quad (6)$$

Step 2: The degree of possibility of $M_2 = (l_2,m_2,u_2) \geq M_1 = (l_1,m_1,u_1)$ is defined as

$$V(M_2 \geq M_1) = \sup[\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad (7)$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \left\{ \begin{array}{ll} 1 & , if \quad m_2 \geq m_1 \\ 0 & , if \quad l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & Otherwise \end{array} \right\} \quad (8)$$

where d is the ordinate of the highest intersection point D between $\mu_{M_1} and \mu_{M_2}$ (Fig. 2). To compare M_1 and M_2, we need both the values of $V = (M_1 \geq M_2)$ and $V = (M_2 \geq M_1)$.

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers, M_i (i = 1,2,. . . ,k) can be defined by

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \text{ and } V(M \geq M_2) \text{ and } \ldots \text{ and } V(M \geq M_k)] = \min V(M \geq M_i), \; i=1,2,\ldots,k. \quad (9)$$

Assume that equation (9) is $d'(A_i) = \min V(S_i \geq S_k)$ (10)

For k = 1,2,…,n; k≠i. Then the weight vector is given by $W' = d'((A_1),(A_2),\ldots,(A_n))^T$ (11) Where A_i are n elements.

Step 4: Via normalization, the normalized weight vectors are $W = (d(A_1),d(A_2),\ldots,d(A_n))^T$ (10)

where W is non-fuzzy number.

4. Proposed supplier selection model

Since this paper has network structure but with a few feedbacks, we cannot use Saaty's supermatrix; because that matrix cannot be converged. Therefore, we use matrix manipulation based on the concept of Dagdeviren et al's and Kahraman et al's as a substitute for Saaty's supermatrix, which is essential and easier to understand.

The proposed model to select preferred supplier is composed of following steps:

Step 1: Identify the factors and sub-factors to be used in the model (Metin and Ihsan, 2008).

Step 2: Structure the ANP model hierarchically (goal, factors, sub-factors) (Metin and Ihsan, 2008).

Step 3: Determine the local weights of the criteria, sub-criteria and each alternatives with each sub-criteria, by using pairwise comparison matrices (assume that there is no dependence among the factors). The fuzzy scale regarding relative importance to measure the relative weights (Kahraman et al., 2006; Cheng et al, 1996)) is given in Fig. 3 and Table 1.

Step 4: Determine the global weight of the sub-criteria considering interdependence among them to resolve the effects of the interdependence that exists between them by matrix w_c which is defined by multiplying matrix B with matrix w_2^T (H.-J. Shyur, 2006).
B: inner dependence matrix of each factor with respect to the other factors.

The decision makers examine the impact of all criteria on each other by using pairwise comparisons as well. Various pairwise comparison matrices are constructed to show for each of the criterion. These pairwise comparison matrices are needed to identify the relative impacts of criteria interdependent relationships. The normalized principal eigenvectors for these matrices are calculated and shown as column component in interdependence weight matrix of criteria B, where zeros are assigned to the eigenvector weights of the sub-criteria from which a given sub-criterion is given.

w_2^T : Local weights of factors matrix, determined in step 3
Step 5: Measure the sub-factors. Linguistic variables proposed by Cheng et al. (1999) are used in this step. The membership functions of these linguistic variables are shown in Fig.4, and the average values related with these variables are shown in Table 2. By using this evaluation scale, the linguistic variables can take different values depending on the structure of the sub-factor.

Step 6: Calculation of gw*sv by synthesizing the results from previous two steps is as follows: Calculate the weight of each supplier by using the simple additive weighting method.

5. Case Study

This case was a joint program between an academic team from the university and an industrial team. The proposed supplier selection method has been applied in one of automotive companies which has 4 main suppliers Fig. 5. Therefore, for the application, a decision committee is established from three managers of the company, each from a different department, and the authors of this paper. Preferred suppliers are selected by using the proposed fuzzy ANP model:

Step 1: In this step 7 criteria, 21 sub-criteria and 4 suppliers, are evaluated by the decision committee

Step 2: The ANP model formed by the factors and sub-factors determined in the first step is shown in Fig. 5. ANP model is composed of four stages. In the first stage, there is the goal of determining sub-factor weights. There are factors, sub-factors and suppliers related to them in second, third and fourth stages respectively.

Step 3: In this step, local weights of the factors and sub-factors which take part in the second and third levels of ANP model, are calculated. Pairwise comparison matrices are formed by the decision committee by using the scale given in Table 1. For example financial criterion and quality criterion are compared using the question ''How important is financial criterion when it is compared with quality criterion?" and the answer ''Weakly more important (WMI)", to this linguistic scale is placed in the relevant cell against the triangular fuzzy numbers (1/2, 2/3, 1). All the fuzzy evaluation matrices are produced in the same manner. Pairwise comparison matrices are analyzed by the Chang's extend analysis method (Section 3.2.1) and local weights are determined. The local weights for the factors are calculated in a similar fashion to the fuzzy evaluation matrices, as shown under Table 3. Pairwise comparison matrices are given in Tables 4-5 together with the local weights. Using the computed relative importance weights, the inner dependence matrix of the factors is constituted in Table 6. Global weight of sub-criteria and FANP computation of overall weight index for alternatives are given in Table 7 and 8 respectively.

Step 4: Global weight of factors, by multiplying matrix B with matrix w_2^T , is given in Table 6.

Step 5: Measure the global weight of sub-factors (gw)

Step 6: The calculation of aggregated weights for each supplier

As it can be perceived by the table 8 we have computed the outcomes of FANP in order to be able to rank suppliers among each other the table shows that the company should contract to the 1st supplier as the best supplier. To validate the results in Section 5, prioritization worksheets were distributed to a group of independent experts in the field. A total of eighteen experts contributed to rank the four suppliers based on their experience. Twenty one criteria were used for evaluation of suppliers based on the company's core competencies (the same criteria applied for the proposed methodology in Table 6). All fifteen returned prioritization worksheets agreed with the prioritization result of proposed methodology (Considering features of second layer suppliers) and three preferred to consider just the first layer of suppliers.

6. Conclusion

In literature, there are so many supplier selection methods which include both MADM and MODM, but none of them did ever enunciated that a supply chain can have more than one layer of suppliers and the other layers can be very effective in total quality of SC and total cost incurred by supply chain. Economic wise, the price of raw materials on the prime cost is an undeniable issue which might result in lowering customer satisfaction and decrease in sale and benefit. The presented article consists of two main parts. The former reveals a new approach of selecting suppliers by having a glance on features of second layer suppliers and the later includes considered criteria and the appropriate tool for solving the introduced approach. These criteria are formed in a network in order to select the best supplier and ANP was considered to be a solution tool. Due to vagueness nature of data, we preferred to utilize fuzzy set theory to overcome this hardship, so the FANP has been used as the proper tool. Then the proposed model has been applied in one of the automotive related companies which supplying parts for OEM is its mission. The model has been solved by one of the common MCDM methods, FANP. The results obtained from the case shows that the new introduced procedure can make the supplier selection process more accurate and also shows a new point of view which has been overlooked up to now.

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Table 1. Linguistic scales for difficulty and importance

Linguistic scale for difficulty	Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	Just equal	(1,1,1)	(1,1,1)
Equally difficult (ED)	Equally important (EI)	(1/2, 1,3/2)	(2/3, 1,2)
Weakly more difficult (WMD)	Weakly more important (WMI)	(1,3/2, 2)	(1/2, 2/3, 1)
Strongly more difficult (SMD)	Strongly more important (SMI)	(3/2, 2,5/2)	(2/5, 1/2, 2/3)
Very strongly more difficult (VSMD)	Very strongly more important (VSMI)	(2,5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more difficult (AMD)	Absolutely more important (AMI)	(5/2, 3,7/2)	(2/7, 1/3, 2/5)

Table 2. Linguistic values and mean of fuzzy numbers.

Linguistic values	The mean of fuzzy number
Very High (VH)	1
High (H)	0.75
Medium (M)	0.5
Low (L)	0.25
Very Low (VL)	0

Table 3. Local weights and pairwise comparison matrix of main factors

Criteria	Financial	Quality	Delivery	Manufacture	Service	Record	Layer2	Weights
Financial	(1,1,1)	(1/2,2/3,1)	(3/2,2,5/2)	(1,3/2,2)	(2,5/2,3)	(1,3/2,2)	(1,3/2,2)	0.208
Quality	(1,3/2,2)	(1,1,1)	(3/2,2,5/2)	(1,3/2,2)	(3/2,2,5/2)	(1,3/2,2)	(1,3/2,2)	0.214
Delivery	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(1,1,1)	(1/2,2/3,1)	(1,3/2,2)	(1,3/2,2)	(2/5,1/2,2/3)	0.104
Manufacture	(1/2,2/3,1)	(1/2,2/3,1)	(1,3/2,2)	(1,1,1)	(1,3/2,2)	(1,3/2,2)	(1/2,2/3,1)	0.144
Service	(1/3,2/5,1/2)	(2/5,1/2,2/3)	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1,3/2,2)	(1/2,2/3,1)	0.081
Record	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,2/3,1)	0.075
Layer 2	(1/2,2/3,1)	(1/2,2/3,1)	(3/2,2,5/2)	(1,3/2,2)	(1,3/2,2)	(1,3/2,2)	(1,1,1)	0.173

Table 4. Local weights and pairwise comparison matrix of Financial sub-factors

Financial	Benefit	Discount	Price	Turnover	Weights
Benefit	(1,1,1)	(2/3,1,2)	(2/5,1/2,2/3)	(1,1,1)	0.189
Discount	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	(1/2,1,3/2)	0.253
Price	(3/2,2,5/2)	(1/2,1,3/2)	(1,1,1)	(3/2,2,5/2)	0.370
Turnover	(1,1,1)	(2/3,1,2)	(2/5,1/2,2/3)	(1,1,1)	0.189

Table 5. The inner dependence matrix of the factors with respect to ‘‘production planning and flexibility”

Manufacture	Kind of equipment	Number of machine	Weights
Kind of equipment	(1,1,1)	(1,3/2,2)	0.68
Number of machine	(1/2,2/3,1)	(1,1,1)	0.32

Table 6. Global weight of sub-criteria

Matrix	Ben	Dis	Pri	Tur	Cer	Edu	FQ	Q.S	ASP	SPC	Acc	Pac	K.M	N.M	P.C	P.P.	N.A.Y	Rep	Gua	Q.M	Rep2	w_2^T	global
Ben	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.189	0.189
Dis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.253	0.253
Pri	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.370	0.370
Tur	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.189	0.189
Cer	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.074	0.074
Edu	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.009	0.009
F.Q.	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.262	0.131
Q.S	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.149	0.149
ASP	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.227	0.113
SPC	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0.279	0.279
Acc	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.500	0.500
Pac	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.500	0.500
K.M	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.34	0	0	0	0	0	0.196	0.326
N.M	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.16	0	0	0	0	0	0.154	0.214
P.C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0.271	0.271
P.P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.379	0.190
N.A.Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.33	0	0	0	0.500	0.667
Rep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0.500	0.167
Gua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1.000	1.000
Q.M2	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0	1	0	0.684	0.929
Rep2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	1	0.316	0.482

Table 7. FANP computation of overall weight index for alternatives

Criteria	weight	Sub-crirteria	global w	scale value	GW*SV	s1	s2	s3	s4
Financial	0.208	Ben	0.189	0.75	0.142	0.271	0.250	0.271	0.209
		Dis	0.253	0.75	0.189	0.299	0.224	0.252	0.224
		Pri	0.370	1	0.370	0.250	0.271	0.271	0.209
		Tur	0.189	0.5	0.094	0.224	0.224	0.299	0.252
Quality	0.214	Cer	0.074	0.5	0.037	0.226	0.270	0.189	0.315
		Edu	0.009	0.5	0.004	0.214	0.239	0.233	0.314
		F.Q.	0.131	1	0.131	0.000	0.000	0.500	0.500
		Q.S	0.149	0.75	0.112	0.191	0.191	0.232	0.385
		ASP	0.113	0.5	0.057	0.276	0.217	0.190	0.317
		SPC	0.279	0.75	0.209	0.270	0.226	0.189	0.315
Delivery	0.104	Acc	0.500	0.75	0.375	0.252	0.224	0.299	0.224
		Pac	0.500	0.5	0.250	0.292	0.122	0.293	0.293
Manufacture	0.144	K.M	0.326	0.5	0.163	0.224	0.252	0.299	0.224
		N.M	0.214	0.5	0.107	0.247	0.237	0.270	0.247
		P.C	0.271	0.75	0.203	0.342	0.158	0.158	0.342
		P.P	0.190	0.75	0.142	0.209	0.271	0.250	0.271
Record	0.081	N.A.Y	0.667	0.75	0.500	0.250	0.250	0.250	0.250
		Rep	0.167	0.75	0.125	0.474	0.175	0.175	0.175
Service	0.075	Gua	1.000	0.5	0.500	0.299	0.252	0.224	0.224
Supplier in layer 2	0.173	Q.M2	0.929	1	0.929	0.500	0.500	0.000	0.000
		Rep2	0.482	0.5	0.241	0.342	0.158	0.342	0.158

Table 8. Comparison of the results of three methods

Supplier	FANP	Rank
1	0.312	1
2	0.276	2
3	0.208	3
4	0.203	4

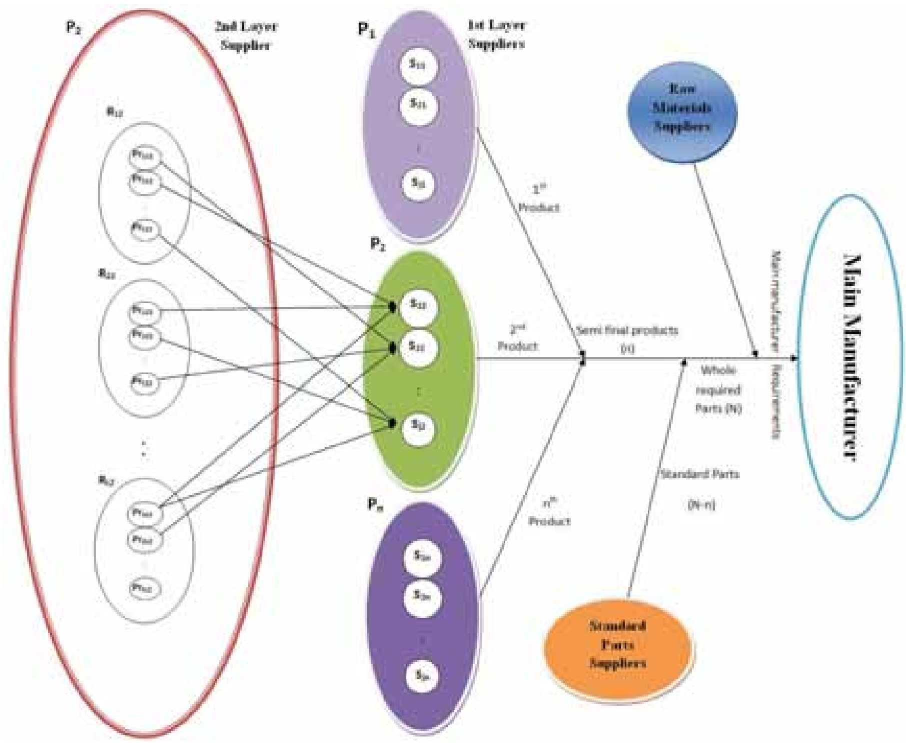

Figure 1. The sequence of 1st and 2nd layer suppliers

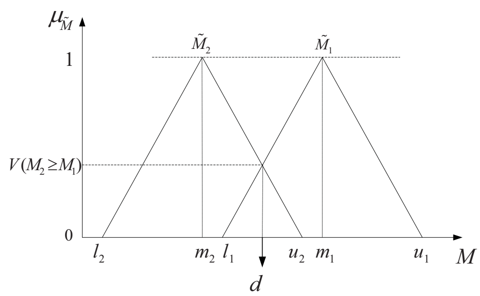

Figure 2. Intersection between M1 and M2

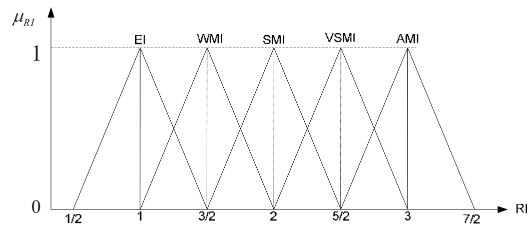

Figure 3. Linguistic scale for relative importance (Kahraman et al., 2006)

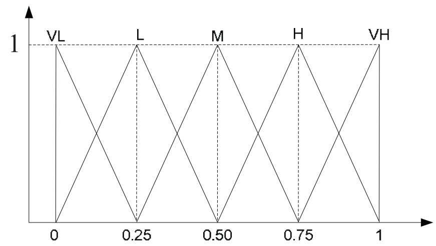

Figure 4. Membership functions of linguistic values for performance indicator rating

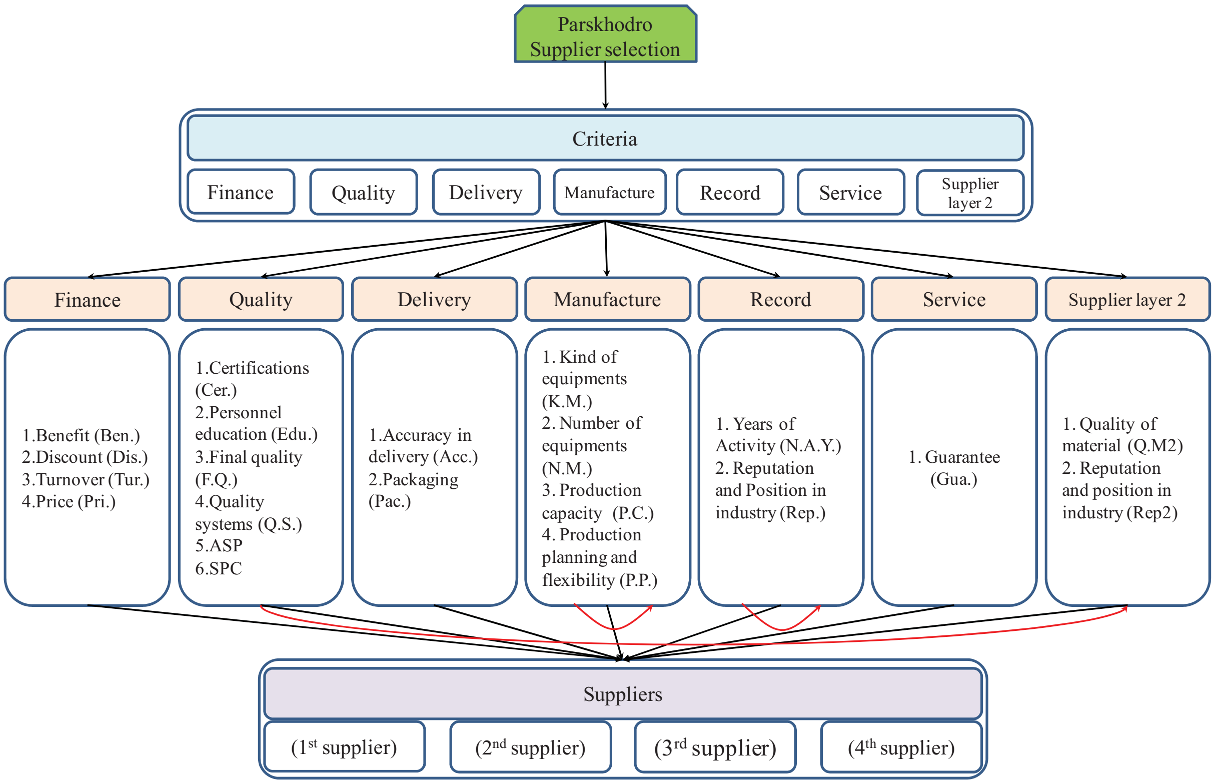

Figure 5. Network of proposed supplier selection model