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Applying a New Integration of MCDM Techniques for Supplier Selection (Case Study: Pars Tire Company)

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Abstract: Nowadays, the problem of supplier selection has emerged as an active research field where numerous research papers have been published around this area within last few years. Supplier selection plays a key role in supply chain management (SCM) and deals with evaluation, ranking and selection of the best option from a pool of potential suppliers especially in the presence of conflicting criteria. In this study, we present a novel conjunctive multiple criteria decision-making (MCDM) approach that addresses dependent relationships among each measurement criteria. As such, we utilize a decision-making trial and evaluation laboratory (DEMATEL), a fuzzy analytical network process (FANP), and a technique of VIKOR to select the best supplier that considers the interdependence and the relative weights of each measurement criterion.

Key words: Supplier Selection. DEMATEL . Fuzzy set . ANP . VIKOR

INTRODUCTION

Supplier selection process has gained importance recently, since the cost of raw materials and component parts constitute the main cost of a product and most of the firms have to spend considerable amount of their revenues on purchasing. Supplier selection is one of the most important decision making problems including both qualitative and quantitative factors to identify suppliers with the highest potential for meeting a firm's needs consistently and at an acceptable cost. Jiang, Zhuang, and Lin (2006) evince the considerable impact of supplier selection and integration on customer satisfaction and business performance.

With the development of information systems, it is becoming an important issue for SCM frameworks and applications to be capable of making decisions on their own (Shemshadi *et al*., 2008 and Soroor *et al*., 2009), and it is not attainable until a well devised decision making process is deployed by an adequately improved software architecture.

Supplier selection is a multi-criteria problem which includes both qualitative and quantitative factors. In order to select the best suppliers it is necessary to make a tradeoff between these tangible and intangible factors some of which may conflict (Ghodsypour & O'Brien, 1998). The objective of supplier selection is to identify suppliers with the highest potential for meeting a firm's needs consistently and at an acceptable cost. Selection is a broad comparison of suppliers using a common set of criteria and measures. However, the level of detail used for examining potential suppliers may vary depending on a firm's needs.

Decision-making trial and evaluation laboratory (DEMATEL) method is adapted to model complex interdependent relationships and construct a relation structure using measurement criteria for innovation evaluation. A fuzzy analytic network process (FANP) is conducted to address the problem of dependence as well as feedback among each measurement criteria. A VIKOR technique is finally utilized to select the best. Here, we combine DEMATEL, Fuzzy ANP and VIKOR approaches to select supplier.

Literature Review:

During recent years supply chain management and supplier selection process have received considerable attention in the literature. Supplier selection is a multi-criteria problem and there are not a lot of efficient techniques or algorithms that address this problem. However three major groups of methods in the literature are mathematical programming models cost based models, and categorical models.

Since supplier selection problems usually have several objectives such as maximization of quality or maximization of profit or minimization of cost, the problem can be modeled using mathematical programming. Weber and Current (1993) proposed a multi-objective approach to supplier selection to aim at minimizing the price, maximizing the quality and on time delivery using systems' constraints and policy constraints in a mixed integer model. Ghodsypour and O'Brien (1998) proposed an integration of AHP and linear programming to consider both tangible and intangible factors in choosing the best suppliers and placing the optimum order quantities among them such that the total value of purchasing becomes maximum. Çebi and Bayraktar (2003) structure the supplier selection problem as an integrated lexicographic goal programming and AHP model including both quantitative and qualitative conflicting factors. Wang, Huang, and Dismkes (2004) use AHP and

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preemptive goal programming based multi-criteria decision-making methodology is then developed to take into account both qualitative and quantitative factors in supplier selection. Wang and Yang (2009) search supplier selection in a quantity discount environment using multi objective linear programming, AHP, and fuzzy compromise programming.

Since price has traditionally been a leading factor, selecting suppliers based on cost has been a common approach. A popular application of the cost approach has been calculating the total cost for each purchase. The total cost of working with each supplier is calculated and the cheapest one is selected. Timmerman (1986) proposes cost–ratio method which collects all costs related to quality, delivery, and services and shows them as a benefit or penalty percentage on unit price. Ellram (1990) explains that a formal total cost approach explicitly recognizes cost factors in addition to price and argues that any total cost approach should include transportation costs, receiving costs, quality costs, purchasing administrative expenses and the price of the item.

Categorical methods are similar to the cost based methods because where the categorical methods determines the best supplier using rating values on relevant supplier performance characteristics, the cost method does same process using dollar figures assigned to the characteristics. Verma and Pullman (1998) examined the difference between managers' rating of the perceived importance of different supplier attributes and their actual choice of suppliers in an experimental setting. Humphreys, Wong, and Chan (2003) presented a framework of environmental criteria which a company can consider during their supplier selection process. In this paper, we try to apply a new integration of techniques that used previously in other area by Chen *et al* (2010).

Methodology:

In this paper, DEMATEL is used to develop interrelations among each measurement criterion. Next, the weights of each criterion are calculated using fuzzy ANP. After that, VIKOR is utilized to rank the alternatives. Finally, we select the best supplier based on these results.

Illustrating Interrelations Among Measurement Criteria:

All factors in a complex system may be either directly or indirectly related; therefore, it is difficult for a decision maker to evaluate a single effect from a single factor while avoiding interference from the rest of the system (Liou *et al*., 2007). In addition, an interdependent system may result in passive positioning; for example, a system with a clear hierarchical structure may give rise to linear activity with no dependence or feedback, which may cause problems distinct from those found in non-hierarchical systems (Tzeng, Chiang, & Li, 2007).

To avoid such problems, the Battelle Geneva Institute created DEMATEL in order to solve difficult problems that mainly involve interactive man-model techniques as well as to measure qualitative and factor-linked aspects of societal problems (Gabus & Fontela, 1972). In addition, DEMATEL has been utilized in numerous contexts, such as industrial planning, decision-making, regional environmental assessment, and even analysis of world problems (Huang, Shyu, & Tzeng, 2007); in all cases, it has confirmed interdependence among criteria and restricted the relations that reflect characteristics within an essential systemic and its developmental trends (Liou *et al*., 2007).

The foundation of the DEMATEL method is graph theory. It allows decision-makers to analyze as well as solve visible problems. In doing so, decision-makers can separate multiple measurement criteria into a cause and effect group to realize causal relationships much more easily. In addition, directed graphs, called digraphs, are much more helpful than directionless graphs since they depict the directed relationships among subsystems. In other words, a digraph represents a communication network or a domination relationship among entities and their groupings (Huang *et al*., 2007).

The steps in DEMATEL are as follows (Liou *et al*., 2007):

Step 1: Calculate the initial average matrix by scores. Sampled experts are asked to point the direct effect based on their perception that each element i exerts on each other element j, as presented by a_{ij}, by utilizing a scale ranging from 0 to 4. No influence is represented by 0, while a very high influence is represented by 4. Based on groups of direct matrices from samples of experts, we can generate an average matrix A in which each element is the mean of the corresponding elements in the experts' direct matrices.

Step 2: Calculate the initial influence matrix. After normalizing the average matrix A, the initial influence matrix D, $[d_{ij}]_{n\times n}$ is calculated so that all principal diagonal elements equal zero. In accordance with D, the initial effect that an element exerts and/or acquires from each other element is given. The map depicts a contextual relationship among the elements within a complex system; each matrix entry can be seen as its strength of influence. This is depicted in Fig. 1; an arrow from d to g represents the fact that d affects g with an influence score of 1. As a result, we can easily translate the relationship between the causes and effects of various measurement criteria into a comprehensible structural model of the system based on influence degree using DEMATEL.

Step 3: Develop the full direct/indirect influence matrix. The indirect effects of problems decreases as the powers of D increase, e.g., to $D^2, D^3, \ldots, D^\infty$, which guarantees convergent solutions to the matrix inversion.

From Fig. 1, we see that the effect of c on d is greater than that of c on g. Therefore, we can generate an infinite series of both direct and indirect effects. Let the (i, j) element of matrix A be presented by a_{ij}, then the direct/indirect matrix can be acquired by following Eq. (1) through (4)

$$\mathbf{D} = s * A, \quad s > 0 \tag{1}$$

Or

$$[d_{ij}]_{n\times n} = s[a_{ij}]_{n\times n}, \; s > 0, \; i, j \in \{1,2,\dots,n\} \tag{2}$$

$$s = Min\left[\frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max_{1\le i\le n}\sum_{i=1}^{n}|a_{ij}|}\right] \tag{3}$$

And

$$\lim_{m\to\infty} \boldsymbol{D}^m = [0]_{n\times n} \quad where\ \boldsymbol{D} = [d_{ij}]_{n\times n}, \; 0 \le d_{ij} < 1 \tag{4}$$

The total-influence matrix T can be acquired by utilizing Eq. (5). Here, I is the identity matrix

$$\boldsymbol{T} = \boldsymbol{D} + \boldsymbol{D^2} + \cdots + \boldsymbol{D^m} = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D})^{-1} \quad \text{when } m \to \infty \tag{5}$$

If the sum of rows and the sum of columns is represented as vector r and c, respectively, in the total influence matrix T, then

$$\boldsymbol{T} = [\boldsymbol{t_{ij}}], \; \boldsymbol{i, j = 1, 2, \dots, n}, \tag{6}$$

$$\mathbf{r} = [r_i]_{n\times 1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{n\times 1} \tag{7}$$

$$\mathbf{c} = [c_j]'_{1\times n} = \left(\sum_{i=1}^{n} t_{ij}\right)_{1\times n} \tag{8}$$

where the superscript apostrophe denotes transposition.

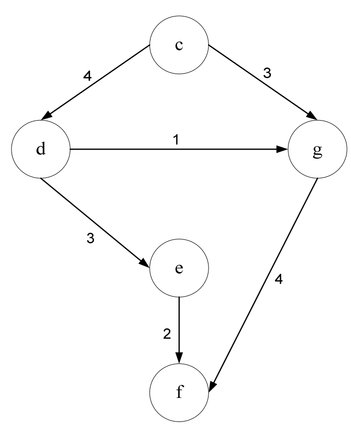

Fig. 1: An influential map

If r_i represents the sum of the ith row of matrix T, then r_i presents the sum of both direct and indirect affects of factor i on all other criteria. In addition, if c_j represents the sum of the jth column of matrix T, then c_j presents the sum of both direct and indirect affects that all other factors have on j. Moreover, note that $j = i(r_i + c_i)$ demonstrates the degree to which factor i affects or is affected by j. Note that if $(r_i - c_i)$ is positive, then factor i affects other factors, and if it is negative, then factor i is affected by others (Liou *et al*., 2007; Tzeng *et al*., 2007).

Step 4: Set the threshold value and generate the impact relations map. Last, we must develop a threshold value. This value is generated by taking into account the sampled experts' opinions in order to filter minor effects presented in matrix T elements. This is needed to isolate the relation structure of the most relevant factors. In accordance with the matrix T, each factor t_{ij} provides information about how factor i affects j. In order to decrease the complexity of the impact relations-map, the decision-maker determines a threshold value for the influence degree of each factor. If the influence level of an element in matrix T is higher than the threshold value, which we denote as p, then this element is included in the final impact relations map (IRM) (Liou *et al*., 2007).

Fuzzy anp:

Fuzzy set theory:

Fuzzy set theory was first developed in 1965 by Zadeh; he was attempting to solve fuzzy phenomenon problems, including problems with uncertain, incomplete, unspecific, or fuzzy situations. Fuzzy set theory is more advantageous than traditional set theory when describing set concepts in human language. It allows us to address unspecific and fuzzy characteristics by using a membership function that partitions a fuzzy set into subsets of members that ‘‘incompletely belong to” or ‘‘incompletely do not belong to” a given subset.

Fuzzzy Numbers:

We order the Universe of Discourse such that U is a collection of targets, where each target in the Universe of Discourse is called an element. Fuzzy number $\widetilde{A}$ is mapped onto U such that a random $x \rightarrow U$ is appointed a real number, $\mu_{\widetilde{A}}(x) \rightarrow [0,1]$. If another element in U is greater than x, we call that element under A.

The universe of real numbers R is a triangular fuzzy number (TFN)$\widetilde{A}$, which means that for $x \in R, \mu_{\widetilde{A}}(x) \in [0,1]$, and

$$\mu_{\widetilde{A}}(x) = \begin{cases} (x-L)/(M-L), & L \leq x \leq M, \\ (U-x)/(U-M), & M \leq x \leq U, \\ 0, & \text{otherwise}, \end{cases}$$

Note that $\widetilde{A} = (L, M, U)$, where L and U represent fuzzy probability between the lower and upper boundaries, respectively, as in Fig. 2. Assume two fuzzy numbers $\widetilde{A}_1 = (L_1, M_1, U_1)$, and $\widetilde{A}_2 = (L_2, M_2, U_2)$; then,

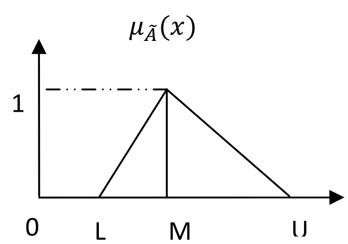

Fig. 2: Triangular fuzzy number

(1) $\widetilde{A}_1 \oplus \widetilde{A}_2 = (L_1, M_1, U_1) \oplus (L_2, M_2, U_2) = (L_1 + L_2, M_1 + M_2, U_1 + U_2)$

(2) $\widetilde{A}_1 \otimes \widetilde{A}_2 = (L_1, M_1, U_1) \otimes (L_2, M_2, U_2) = (L_1L_2, M_1M_2, U_1U_2), L_i > 0, M_i > 0, U_i > 0$

(3) $\widetilde{A}_1 - \widetilde{A}_2 = (L_1, M_1, U_1) - (L_2, M_2, U_2) = (L_1 - L_2, M_1 - M_2, U_1 - U_2)$

(4) $\widetilde{A}_1 \div \widetilde{A}_2 = (L_1, M_1, U_1) \div (L_2, M_2, U_2) = \left(\frac{L_1}{L_2}, \frac{M_1}{M_2}, \frac{U_1}{U_2}\right), L_i > 0, M_i > 0, U_i > 0$

(5) $\widetilde{A}_1^{-1} = (L_1, M_1, U_1)^{-1} = \left(\frac{1}{U_1}, \frac{1}{M_1}, \frac{1}{L_1}\right), L_i > 0, M_i > 0, U_i > 0$

Fuzzy Linguistic Variables:

The fuzzy linguistic variable is a variable that reflects different aspects of human language. Its value represents the range from natural to artificial language. When the values or meanings of a linguistic factor are being reflected, the resulting variable must also reflect appropriate modes of change for that linguistic factor. Moreover, variables describing a human word or sentence can be divided into numerous linguistic criteria, such as equally important, moderately important, strongly important, very strongly important, and extremely important, as shown in Fig. 3; definitions and descriptions are shown in Table 1. For the purposes of the present study, the 5-point scale (equally important, moderately important, strongly important, very strongly important and extremely important) is used.

Analytic Network Process:

The purpose of the ANP approach is to solve problems involving interdependence and feedback among criteria or alternative solutions. ANP is the general form of the analytic hierarchy process (AHP), which has been used in multi-criteria decision-making (MCDM) in order to consider non-hierarchical structures. MCDM has been applied to project selection, product planning, and so forth (Ong, Huang, & Tzeng, 2004).

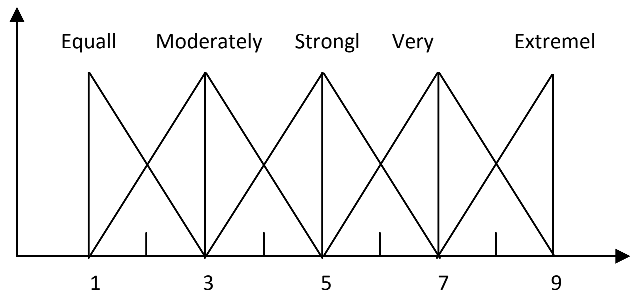

Fig. 3: A fuzzy membership function for linguistic variable attributes

Table 1: Definition and membership function of fuzzy number

Fuzzy number	Linguistic variable	Triangular fuzzy number
$\tilde{9}$	Extremely important/preferred	(7,9,9)
$\tilde{7}$	Very strongly important/preferred	(5,7,9)
$\tilde{5}$	Strongly important/preferred	(3,5,7)
$\tilde{3}$	Moderately important/preferred	(1,3,5)
$\tilde{1}$	Equally important/preferred	(1,1,3)

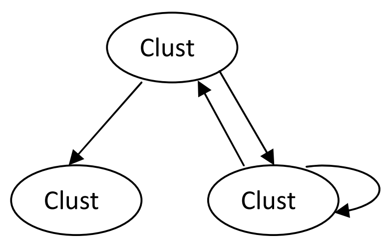

Fig. 4: Case 1 structure

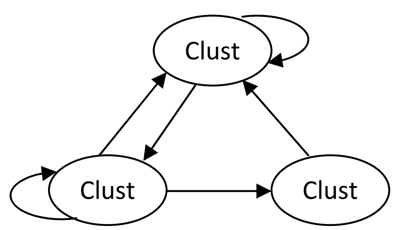

Fig. 5: Case 2 structure

The first phase of ANP compares the measuring criteria in the overall system to form a super matrix. This can be accomplished using pair-wise comparisons. The relative importance-values of pair-wise comparisons can be categorized from 1 to 9 in order to represent pairs of equal importance (1) to extreme inequality in importance (9) (Saaty, 1980). The following is the general form of the super matrix (Liou *et al*., 2007):

$$
\boldsymbol{W} = \begin{array}{c} C_1 \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1m_1} \end{array} \\ C_2 \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2m_2} \end{array} \\ \vdots \quad \vdots \\ C_n \begin{array}{c} e_{n1} \\ e_{n2} \\ \vdots \\ e_{nm_n} \end{array} \end{array}
\overset{\begin{array}{cccc} C_1 & C_2 & \cdots\cdots & C_n \\ e_{11}\ldots e_{1m_1} & e_{21}\ldots e_{2m_2} & & e_{n1}\ldots e_{nm_n} \end{array}}{\begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1n} \\ W_{12} & W_{22} & \cdots & W_{2n} \\ \vdots & \vdots & \vdots\vdots\vdots & \vdots \\ W_{n1} & W_{n2} & \cdots & W_{nn} \end{bmatrix}}
$$

Where c_m denotes the mth cluster, e_{mn} denotes the mth element in the mth cluster; and W_{ij} is the principal eigenvector of the influence of the elements compared in the jth cluster to the ith cluster. In addition, if the jth cluster has no influence to the jth cluster, then $W_{ij} = 0$.

Thus, the form of the super matrix relies on the variety of its structure. There are several structures that were proposed by Saaty including hierarchy, holarchy, suparchy, and so on (Ong *et al*., 2004). In order to demonstrate how the structure is affected by the super matrix, Ong *et al* (2004) offer two simple cases that both involve three clusters to show how to form the super matrix in accordance with different structures (see Fig. 4).

Based on Fig. 4, the super matrix can be formed as:

$$
W = \begin{array}{c} C_1 \\ C_2 \\ C_3 \end{array} \overset{\begin{array}{ccc} C_1 & C_2 & C_3 \end{array}}{\begin{bmatrix} 0 & 0 & W_{13} \\ W_{21} & 0 & 0 \\ W_{31} & 0 & W_{33} \end{bmatrix}}
$$

In Fig. 5, a case more complex than that depicted in Fig. 4 is shown. Based on Fig. 5, the super matrix can be formed as:

$$
W = \begin{array}{c} C_1 \\ C_2 \\ C_3 \end{array} \overset{\begin{array}{ccc} C_1 & C_2 & C_3 \end{array}}{\begin{bmatrix} W_{11} & W_{12} & W_{13} \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & 0 \end{bmatrix}}
$$

After forming the super matrix, the weighted super matrix is generated by transforming all column sums to unity (Ong *et al*., 2004).

Then, we use the weighted super matrix to generate a limiting super matrix by using Eq. (9) to calculate global weights.

$$\lim_{k\to\infty} \boldsymbol{W}^k \tag{9}$$

In this step, if the super matrix shows signs of cyclicity, then there exists more than one limiting super matrix. That is, there are two or more limiting super matrices, and the Cesaro sum must be calculated to obtain the priority among these matrices. The Cesaro sum is calculated using Eq. (10).

$$\lim_{k\to\infty} \left(\frac{1}{N}\right) \sum_{k=1}^{N} \boldsymbol{W}^k \tag{10}$$

Eq. (10) calculates the average effect of a limiting super matrix; otherwise, the super matrix can be raised to a large power to generate the priority weights.

The steps of the fuzzy ANP calculation are provided as follow:

Step 1: Confirm both dimensions and criteria of the model.

Step 2: Develop the ANP model hierarchically using the dimensions, and criteria.

Step 3: Determine the local weights of both dimensions and criteria by utilizing pair-wise comparison matrices. Assume that there is no dependence between each. The relative importance-values of pair-wise comparisons are provided in Table 1.

Step 4: Determine the inner dependence matrix of each dimension with respect to other dimensions. In Step 3, the dependence of local weights in the inner matrix was calculated, such that this step is intended to calculate the interdependent weights of the dimensions.

Step 5: Calculate the global weights for the sub-factors. This can be done by multiplying the local weight of each sub-factor with the interdependent weights associated with dimensions where it belongs.

Vikor:
Introduction to vikor:

The VIKOR method is a compromise MADM method, developed by Opricovic .S and Tzeng (Opricovic, 1998; Opricovic, S. and Tzeng, G. H., 2002) started from the form of Lp-metric:

$$L_{pi} = \left\{ \sum_{j=1}^{n} \left[w_j (f_j^* - f_{ij}) / (f_j^* - f_j^-) \right]^p \right\}^{1/p} \quad 1 \le p \le +\infty \,; i = 1,2, \dots I.$$

The VIKOR method can provide a maximum ''group utility'' for the "majority'' and a minimum of an individual regret for the ''opponent'' (Opricovic, 1998; Opricovic, S; Tzeng, G. H., 2002; Serafim Opricovic & Gwo-Hshiung Tzeng, 2004).

Working Steps Of Vikor Method:

1) Calculate the normalized value

Assuming that there are m alternatives, and n attributes. The various I alternatives are denoted as x_i. For alternative x_j, the rating of the jth aspect is denoted as x_{ij}, i.e. x_{ij} is the value of jth attribute. For the process of normalized value, when x_{ij} is the original value of the ith option and the jth dimension, the formula is as follows:

$$f_{ij} = x_{ij} / \sqrt{\sum_{j=1}^{n} x_{ij}^2} \quad , i = 1,2, \dots, m \,; j = 1,2, \dots \,, n \tag{11}$$

2) Determine the best and worst values

For all the attribute functions the best value was f_j^* and the worst value was f_j^-, that is, for attribute J=1-n, we get formulas (12) and (13)

$$f_j^* = \max \quad f_{ij} \,, i = 1,2, \dots, m \tag{12}$$

$$f_j^- = \min \quad f_{ij} \,, i = 1,2, \dots, m \tag{13}$$

Where f_j^* the positive ideal solution for the jth criteria is, f_j^- is the negative ideal solution for the jth criteria. If one associates all f_j^*,one will have the optimal combination, which gets the highest scores, the same asf_j^-.

3) Determine the weights of attributes

The weights of attribute should be calculated to express their relative importance.

4) Compute the distance of alternatives to ideal solution

This step is to calculate the distance from each alternative to the positive ideal solution and then get the sum to obtain the final value according to formula (14) and (15).

$$S_i = \sum_{j=1}^{n} w_j (f_j^* - f_{ij}) / (f_j^* - f_j^-) \tag{14}$$

$$R_i = \max_j \left[w_j (f_j^* - f_{ij}) / (f_j^* - f_j^-) \right] \tag{15}$$

Where S_i represents the distance rate of the ith alternative to the positive ideal solution (best combination), R_i represents the distance rate of the ith alternative to the negative ideal solution (worst combination). The excellence ranking will be based on S_i values and the worst rankings will be based on R_i values. In other words, S_i, R_i indicate L_{1i} and L_{*i} of L_p-metric respectively.

5) Calculate the VIKOR values Q_i for i=1,2, … ,m, which are defined as

$$Q_i = v \left[\frac{S_i - S^*}{S^- - S^*} \right] + (1 - v) \left[\frac{R_i - R^*}{R^- - R^*} \right] \tag{16}$$

Where $S^- = \max_i S_i$, $S^* = \min_i S_i$, $R^- = \max_i R_i$, $R^* = \min_i$, R_i , and v is the weight of the strategy of "the majority of criteria'' (or ''the maximum group utility''). $[(S - S^*)/(S^- - S^*]$ represents the distance rate from the positive ideal solution of the ith alternative's achievements In other words, the majority agrees to use the rate of the ith.$[(R - R^*)/(R^- - R^*]$ represents the distance rate from the negative ideal solution of the ith alternative; this means the majority disagree with the rate of the ith alternative. Thus, when the v is larger (>

0.5), the index of Q_i will tend to majority agreement; when v is less (< 0.5), the index Q_i will indicate majority negative attitude; in general, v = 0.5, i.e. compromise attitude of evaluation experts.

6) Rank the alternatives by Q_i values

According to the Q_i values calculated by step (4), we can rank the alternatives and to make-decision.

Case Study:

The Pars Tire Company is a large, well known manufacturer that produces tires in Iran. For developing new products, its board of directors wishes to select material suppliers to purchase key components in order to achieve the competitive advantage in the market. A decision committee has been formed to select a supplier from three qualified supplier's S1; S2; S3.

Determining Dimension And Criteria For Selecting Supplier:

The large number of criteria that should typically be considered in selecting the best supplier , Using the structure of the seven aspects as the base and synthesizing the other literature, in current study dimension including :Flexibility (D1), Delivery (D2), Assurance of Supply (D3), Cost (D4), Quality (D5), Organizational Strategic Issues & Perceived Risks (D6), and Environmental Issues (D7). Each dimension has three to six measurement criteria (Table 2).Their ranking of each measurement criterion was ascertained by adapting a 5-point scale, as shown in Table 3.

Table2. Selecting the best supplier

Goal	Evaluating dimensions	Evaluating criteria
Selecting Supplier	D1 : Flexibility	C1 :Capacity
		C2 : Inventory Availability
		C3: Customization
		C4: Negotiability
		C5: Information Sharing
		C6: Availability of Raw materials
	D2: Delivery	C7: Total Order Lead time
		C8: Geographic Location
		C9: Trade Restrictions
	D3:Assurance of Supply	C10: Shipment Accuracy (On Time)
		C11: Shipment Accuracy (On Quantity)
		C12:Warranty Policies
	D4: Cost	C13: Supplier's Selling Price
		C14: Logistic Cost
		C15: Value –Added Cost
	D5: Quality	C16: Certification
		C17: Customer Service
		C18: Commitment to Quality
	D6: Organizational Strategic Issues & Perceived Risks	C19: Company`s Financial Situation
		C20: Company Past Record/ Reputation in The Field
		C21:Political Stability/Governmental Policy
		C22: Legal System
		C23: Stable Workforce
	D7: Environmental Issues	C24: Environmental Management Plan
		C25: Environmental Certifications

Evaluating The Relationship Among Each Dimension:

The purpose of this paper is to determine the best supplier and evaluate the relationships among such criteria. Sixty-six experts were asked to indicate the relationships between seven measurement dimensions. Based on an average of their opinions, we formed an initial direct-relation 7 × 7 matrix A by using pair-wise comparisons (see Table 3).

Table 3: The average initial direct – relation 7×7 matrix **A**

	D1	D2	D3	D4	D5	D6	D7
D1	0	0.15	1.68	1.25	2.63	1.32	1.29
D2	2.40	0	2.33	2.63	2.77	1.29	0.71
D3	3.50	3.76	0	3.42	2.20	3.78	0.04
D4	2.31	0.24	0.26	0	0.30	1.75	1.22
D5	1.01	2.93	3.35	1.22	0	3.63	1.32
D6	1.72	1.25	2.63	1.32	1.29	0	1.10
D7	2.21	3.03	3.42	1.10	3.78	2.30	0

In accordance with Eq. (1) through (3), we next generated the normalized direct-relation matrix D from A. After that, Eq. (5) is used to calculate the total influence matrix T, as show in Table 4. Finally, Eq. (7) and (8) are utilized to calculate total influences given and received along each of these measurement dimensions; the result of these calculations is given in Table 5.

Table 4. Total influence matrix **T**

	D1	D2	D3	D4	D5	D6	D7
D1	0.1923	0.1880	0.2936	0.2363	0.3212	0.2921	0.1626
D2	0.3868	0.2180	0.3809	0.3657	0.3840	0.3550	0.1630
D3	0.5083	0.4518	0.3228	0.4637	0.4160	0.5360	0.1637
D4	0.2523	0.1196	0.1522	0.1066	0.1473	0.2299	0.1326
D5	0.3655	0.4174	0.4808	0.3395	0.2827	0.5128	0.2071
D6	0.3112	0.2548	0.3522	0.2633	0.2733	0.2327	0.1578
D7	0.4742	0.4758	0.5462	0.3786	0.5350	0.5138	0.1619

Table 5. The sum of influences on measurement dimension

	$r_i + c_i$	$r_i - c_i$
D1	4.1768	-0.8044
D2	4.3786	0.1282
D3	5.3910	0.3336
D4	3.2940	-1.0133
D5	4.9652	0.2462
D6	4.5176	-0.8270
D7	4.2341	1.9367

Calculating Weights Of Criteria In Selecting Supplier:

In this stage, we used fuzzy ANP to calculate the weights of measurement .At first; the relative importance of relationships among measurement criteria resembles the impact relations map. Note again that pair-wise comparisons were conducted according to Table 4 above. Table 6 illustrates the local weight, which is acquired using the principle eigenvector of comparison between criterion 1 and criteria 13 through 15.

Table 6: The illustration of the local weight of criteria 13 through 15 under the effect of criterion 1

Measurement Criteria	C13			C14			C15			Local Weight
C13	1.00	1.00	3.00	1.91	3.31	4.27	0.14	0.18	0.31	0.22
C14	0.23	0.30	0.52	1.00	1.00	3.00	0.19	0.28	0.49	0.12
C15	3.18	5.66	7.10	2.02	3.60	5.13	1.00	1.00	3.00	0.66

From the Eq. (9), we calculated the limiting power of the unweighted matrix until it reached stability; the results are provided in Table 7. The entries in the same row are the global weights of each measurement criterion.

Ranking Alternatives In Order To Select The Best Supplier:

In this paper, Pars Tire Company has three suppliers that want to select best of them. Based on the responses of these eight experts and the global weights of measurement criteria, as shown in Table 7, we utilized VIKOR to rank the three suppliers, which can be considered alternative solutions for our purposes here. Following the steps of VIKOR, we generated values necessary to rank these types of suppliers, as shown in Table 8. We also present the overall results of this study in Table 9. As you see in the Table 9, A1 is the best supplier for Pars Tire Company.

Table 7: The weighted matrix of measurement criteria

	C1	C2	C3	C4	...	C22	C23	C24	C25
C1	0.0495	0.0495	0.0495	0.0495	…	0.0495	0.0495	0.0495	0.0495
C2	0.1308	0.1308	0.1308	0.1308	…	0.1308	0.1308	0.1308	0.1308
C3	0.0306	0.0306	0.0306	0.0306	…	0.0306	0.0306	0.0306	0.0306
C4	0.0625	0.0625	0.0625	0.0625	...	0.0625	0.0625	0.0625	0.0625
C22	0.0097	0.0097	0.0097	0.0097	…	0.0097	0.0097	0.0097	0.0097
C23	0.0036	0.0036	0.0036	0.0036	…	0.0036	0.0036	0.0036	0.0036
C24	0.0021	0.0021	0.0021	0.0021	…	0.0021	0.0021	0.0021	0.0021
C25	0.0002	0.0002	0.0002	0.0002	…	0.0002	0.0002	0.0002	0.0002

Table 8: The result of supplier ranking by VIKOR

Wed M	C1	C2	C3	...	C23	C24	C25	$E_i=\Sigma e_i$	F_i	P_i	ranking
supplier 1	0.6227	0.5487	0.5577	…	0.5730	0.6093	0.5629	0.4130	0.2501	0.5400	1
supplier 2	0.5631	0.5944	0.5514	…	0.5666	0.5574	0.5690	0.4216	0.2281	0.5072	3
supplier 3	0.5432	0.5879	0.6204	…	0.5921	0.5639	0.5996	0.3108	0.2304	0.5222	2
W	0.0495	0.1308	0.0306	…	0.0036	0.0021	0.0002				

Table 9: The overall result of this study

Goal	Evaluating Dimensions	Evaluating Criteria (After considered interrelationships)	Global Weights	supplier	Overall Ranking
Selecting the best supplier	D1 : Flexibility	C1	0.0495	supplier 1	1
		C2	0.1308		
		C3	0.0306		
		C4	0.0625		
		C5	0.1099		
		C6	0.0371		
	D2: Delivery	C7	0.0006	supplier 2	3
		C8	0.0003		
		C9	0.0003		
	D3:Assurance of Supply	C10	0.0003		
		C11	0.0020		
		C12	0.0025		
	D4: Cost	C13	0.1127		
		C14	0.0475		
		C15	0.2997		
	D5: Quality	C16	0.0062	supplier 3	2
		C17	0.0003		
		C18	0.0006		
	D6: Organizational Strategic Issues & Perceived Risks	C19	0.0603		
		C20	0.0279		
		C21	0.0028		
		C22	0.0097		
		C23	0.0036		
	D7: Environmental Issues	C24	0.0021		
		C25	0.0002		

Conclusions:

Supplier selection is a broad comparison of suppliers using a common set of criteria and measures to identify suppliers with the highest potential for meeting a firm's needs consistently and at an acceptable cost. Selecting the right suppliers significantly reduces the purchasing costs and improves corporate competitiveness therefore supplier selection one of the most important decision making problems. In this study, we have combined DEMATEL, fuzzy ANP and VIKOR approaches to select the best supplier that considers the interdependence and relative weights of each measurement criterion and different types of suppliers. The results of the current study indicate that A1 is the best supplier for this company.

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