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A Novel Technique to Solve the Supplier Selection Problems: Combination of Decision Making Trial & Evaluation Laboratory, Graph Theory and Matrix Approach Methods

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GTMA

ABSTRACT

Considering the major change occurred in business cells from plant to "chain" and the critical need to choose the best partners to form the supply chain for competing in today's business setting, one of the vital decisions made at the early steps of constructing a business is supplier selection. Given the fact that the early decisions are inherently strategic and therefore hard and costly to change, it's been a point of consideration for industries to select the right supplier. It's clear that different criteria must be investigated and interfered in deciding on the best partner(s) among the alternatives. Thereupon the problem might be regarded as a multiple criteria decision making (MCDM) problem. There are a variety of techniques to solve a MCDM problem. In this paper we propose a novel technique by combination of decision making trial and evaluation laboratory and graph theory and matrix approach techniques. Eventually, the results are compared to three common techniques, including SAW (current used technique), TOPSIS and VIKOR, and discussed to come to a conclusion.

1. Introduction

Today's business environment is a turbulent, variable and uncertain environment. Wide range, numerous and basic changes in business setting has caused a change in strategic view and applied tools and methods, shortened product life cycle and a dramatic decline in worthiness of historical data in comparison to not many years ago. One of the major changes, which have befallen mostly in the 1990s [1], is the change in business unit from plant or firm to chain. There is no longer a contest between firms. Firms have come together as partners forming supply chains. In some parts of the literature, it is identified that the supply chain must be considered as the principal unit of competitive analysis[2]. Therefore the key to success in today's business world is to form a powerful chain of suppliers which not only are able to perform in an eye catching way by themselves as individuals, but also are capable of having a great performance in integration with each other as a whole. Hence the term supply chain management was adopted to describe the

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new concept which was replacing the traditional idea of buying and logistics[1]. The term supply chain management which was appeared in 1980s and used popularly in 1990s[3] is defined as "the systematic, strategic coordination of the traditional business tasks and the tactics across these business tasks within a special company and across businesses within the supply chain in order to enhance the long-run efficiency of the individual companies and the supply chain as a whole"[4].

No doubt there is a necessity of coordination and harmony for a supply chain to surpass the rivals. However, the first step which must be taken with special care is the selection of partners. The unique sensitiveness of this step has lied in the fact that facing long term problems or goals accomplishment over a long period is up to the accuracy of supplier selection. In other words, this is a strategic decision which has to encompass all the aspects which influence the future business stature of a company. That is the reason why deciding on the right supplier has become a central point of consider to the researchers in supply chain management (SCM) resulting in a large number of decision methods and approaches in recent years [5-10]. Nevertheless, the features of this decision-making procedure have not yet been structured[11]. Selecting the suitable supplier to start partnership needs a comprehensive view.

Deciding on which supplier to purchase from not only influences the cost of purchasing elements, materials and services, but also has a major effect on whether a relationship lasts for long. To avoid risk of missing a perfect view, a variety of factors must be taken into account for candidates to choose from. Though it is clear that the supplier selection is a problem that needs to have multiple factors as the determinants of the best supplier(s), there is not a common and constant set of factors to be considered in different cases. As a result, given the situation including the element or material whose supplier is aimed to be selected, its currency, etc. the criteria which are interfered in a solution vary in number and inherence. Dickson [12], Ellram [13], Stamm and Golhar [14], Sanayei et al. [15] identified, respectively 60, 18, 23 and 5 criteria to realize the best supplier.

2. Material and Method

Given that the proposed methodology is based on a combination of DEMATEL and GTMA techniques, in this section a description of the two techniques will be given individually and subsequently the proposed technique will be elaborated in Theory and calculation section.

2.1. DEMATEL Method

The DEMATEL method is resulted from the Geneva Research Centre of the Battelle Memorial Institute [16, 17]. For imagining the construction of complex causal relationships with matrices or digraphs, it is particularly applicable and useful. The matrices or digraphs depict a contextual relationship between the components of the system, in which a number shows the strength of influence. therefore, the DEMATEL method can transform the relationship between the causes and effects of criteria into an comprehensible structural model of the system[18]. The DEMATEL method has been successfully used in many areas [19-22]. The fundamentals of the DEMATEL method assume that a system includes a series of criteria $C = \{C_1, C_2, . . .,C_n\}$, and regarding a mathematical relation, the specific pair wise relations are determined for modeling. The solving steps are as follows:

Step 1: *Generating the direct relation matrix.* Measuring the relationship between criteria requires that the comparison scale be designed as four levels: 0(no influence),1(low influence), 2(high influence), 3(very high influence), 4(very high influence). Experts make sets of the pair wise comparisons in terms of influence and direction between criteria, the initial data can be obtained as the direct-relation matrix that is a n x n matrix A, in which a_{ij} is denoted as the degree to which the criteria affects the criteria j.

Step 2: Normalizing the direct relation matrix. On the base of the direct – relation matrix A, the normalized direct-relation matrix X can be obtained through the following formulas:

$$X = k \times A \tag{1}$$

$$k=\frac{1}{\max \sum_{1}^{n} a_{ij}} \tag{2}$$

Step 3: Attaining the total relation matrix. Once the normalized direct-relation matrix X is obtained, the total relation matrix M can be acquired by using formula (3), in which **I** is denoted as the identity matrix:

$$M = X\,(I - X)^{-1} \tag{3}$$

Step 4: Producing a causal diagram. The sum of rows and the sum of columns are separately denotes as vectors D and vector R through formula (4) and (6). The horizontal axis vector (D+R) named "Prominence" is made by adding D to R, which reveals how much importance the criterion has. Similarly, the vertical axis (D–R) named "Relation" is made by subtracting D from R, which may group criteria into a cause group. Or, if the (D - R) is negative, the criterion is grouped into the effect group. Therefore, the causal diagram can be acquired by mapping the dataset of the (D + R, D - R), providing valuable insight for making decisions.

$$T = [t_{ij}]_{n\times n}\,, \qquad i, j = 1, 2, ..., n \tag{4}$$

$$D = [\sum_{j=1}^{n} t_{ij}] = [t_i]_{n\times 1} \quad (5)$$

$$R = [\sum_{i=1}^{n} t_{ij}] = [t_i]_{n\times 1} \quad (6)$$

In these equations, vector **D** and vector **R** denote the sum of rows and the sum of columns from total-relation matrix M= $[m_{ij}]_{n\times n}$, respectively,

Step 5: Obtaining the inner dependence matrix. In this step, the sum of each column in total-relation matrix is equal to 1 by the normalization method, and then the inner dependence matrix can be acquired [18].

2.2. The Graph Theory and Matrix Approach

Graph theory is a rational and systematic method. In his book, Rao [23]‘‘Decision making in the manufacturing environment: using graph theory and fuzzy multiple attribute decision making methods” introduces this method and illustrates some of its functions.

In several areas of science and technology, Graph/digraph model representations have demonstrated to be useful for modeling and analyzing various kinds of systems and problems [24]. The matrix approach is useful for analyzing the graph/digraph models efficiently to derive the system function and index to realize the objectives[23]. The graph theory and matrix methods are composed of the digraph display, the matrix representation and the permanent function exhibition. The digraph is the visual display of the variables and their mutual dependences. The matrix transforms the digraph into mathematical structure and the constant function is a mathematical exhibition that assists to determine the numerical indicator[25].

The step by step explanation of the methodology is as follows:

Step 1. Identifying supplier selection attributes. In this step all the criteria which affect the decision is determined. This can be done by using relevant criteria available in the literature or getting information from the decision maker.

Step 2. Determine supplier alternatives. All potential alternatives for the project are identified.

Step 3. Graph representation of the criteria and their interdependencies. Supplier selection criterion is defined as a factor that influences the selection of an alternative for supplier. The supplier selection criteria digraph models the alternative selection criteria and their interrelationship. This digraph consists of a set of nodes N ={n_i}, with i = 1, 2,...,M and a set of directed edges E ={e_{ij}}. A node n_i represents i-th alternative selection criterion and edges represent the relative importance among the criteria. The number of nodes M considered is equal to the number of alternative selection criteria considered. If a node ‘i’ has relative importance over another node ‘j’ in the alternative selection, then a directed edge or arrow is drawn from node i to node j (i.e. e_{ij}). If ‘j’ has relative importance over ‘i’ directed edge or arrow is drawn from node j to node i (e_{ji}) [23].

Step 4. Developing supplier selection criteria matrix of the graph. Matrix representation of the alternative selection criteria digraph gives one-to-one representation. A matrix here called the supplier selection criteria matrix. This is an M in M matrix and considers all of the criteria (i.e. A_i) and their relative importance (i.e. a_{ij}). Where A_i is the value of the i-th criteria represented by node n_i and a_{ij} is the relative importance of the i-th criteria over the j-th represented by the edge e_{ij} [23, 25].

The value of A_i should preferably be obtained from available or estimated data. When quantitative values of the criteria are available, normalized values of a criterion assigned to the alternatives are calculated by v_i/v_j, where $\boldsymbol{v_i}$ is the measure of the criterion for the i-th alternative and $\boldsymbol{v_j}$ is the measure of the criterion for the j-th alternative which has a higher measure of the criterion among the considered alternatives. This ratio is valid for beneficial criteria only. A beneficial criteria means its higher measures are more desirable for the given application.

Whereas, the non-beneficial criterion is the one whose lower measures are desirable and the normalized values assigned to the alternatives are calculated by v_j/v_i. In this case, v_j is the measure of the criterion for the j-th alternative which has a lower measure of the criterion among the considered alternatives. If a quantitative value is not available, then a ranked value judgment on a fuzzy conversion scale is adopted. By using fuzzy set theory, the value of the criteria (A_i) can be first decided as linguistic terms, converted into corresponding fuzzy numbers and then converted to the crisp scores [26].

Cheng and Hwang have proposed a numerical approximation system to systematically convert linguistic terms to their corresponding fuzzy numbers. It contains eight conversion scales and in the present work, an 11-point scale is considered [26, 27].

Once a qualitative criterion is represented on a scale then the normalized values of the criterion assigned for different alternatives are calculated in the same manner as that for quantitative criteria. The relative importance between two criteria (i.e. a) is also assigned value on a fuzzy conversion scale, similar to the one described above.

The relative importance implies that a criterion ‘i’ is compared with another criterion ‘j’ in terms of relative importance for the given problem. The relative importance is expressed in 11 classes that lead to minimization of subjectivity to a large extent while deciding the relative importance between two selections criteria. It may be mentioned that one may choose any scale, e.g., 0–5, 0–10, 0–50, 0–100 for A_i ’s and a_{ij} ’s but the final ranking will not change as these are relative values. It is, however, desirable to choose a lower scale for A_i's and a_{ij}'s to obtain a manageable value of the index and also to reduce subjectivity [25, 28].

$$C_S\ Matrix = \begin{matrix} A_1 & a_{12} & a_{13} & a & a & a_{1.m} \\ a_{21} & A_2 & a_{23} & \cdots & \cdots & a_{2.m} \\ a_{31} & a_{32} & A_3 & \cdots & \cdots & a_{3.m} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{M1} & a_{M2} & a_{M3} & \cdots & \cdots & A_m \end{matrix} \qquad (7)$$

Step 5. Obtaining alternative selection criteria function for the matrix. The permanent of this matrix, is defined as the alternative selection criteria function. The permanent of a matrix was introduced by Cauchy in 1812. At that time, while developing the theory of determinants, he also defined a certain subclass of symmetric functions which later Muir named permanents [29]. The permanent is a standard matrix function and is used in combinatorial mathematics[25, 26]. The permanent function is obtained in a similar manner as the determinant, but unlike in a determinant where a negative sign appears in the calculation, in a variable permanent function positive signs replace these negative signs [25, 26]. Application of the permanent concept will lead to a better appreciation of selection attributes. Moreover, using this no negative sign will appear in the expression (unlike determinant of a matrix in which a negative sign can appear) and hence no information will be lost [26].

The per(C_S) contains terms arranged in (M + 1) groups, and these groups represent the measures of criteria and the relative importance loops. The first group represents the measures of M criteria. The second group is absent as there is no self-loop in the digraph. The third group contains 2- criterion relative importance loops and measures of (M-2) criteria. Each term of the fourth group represents a set of a 3-criterion relative importance loop, or its pair, and measures of (M-3) criteria.

The fifth group contains two sub-groups. The terms of the first sub-group is a set of two 2-criterion relative importance loops and the measures of (M-4) criteria. Each term of second sub-group is a set of a 4-attribute relative importance loop, or its pair, and the measures of (M-4) criteria.

The sixth group contains two subgroups. The terms of the first sub-group are a set of a 3-criterion relative importance loop, or its pair, and 2-criterion importance loop and the measures of (M-5) criteria. Each term of the second sub-group is a set of a 5-criterion relative importance loop, or its pair, and the measures of (M-5) criteria. Similarly other terms of the equation are defined. Thus, the C_S fully characterizes the considered alternative selection evaluation problem, as it contains all possible structural components of the criteria and their relative importance. [24]

$$Per\ (C_s) = \prod_{i=1}^{M} A_i + \sum_{i=1}^{M-1} \sum_{j=i+1}^{M} \dots \sum_{M=t+1}^{M} (a_{ij} a_{ji})\, A_k A_l A_m A_n A_o \dots A_t A_M$$

$$+\sum_{i=1}^{M-2} \sum_{j=i+1}^{M-1} \sum_{k=i+1}^{M} \dots \sum_{M=t+!}^{M} (a_{ij} a_{jk} a_{ki} + a_{ik} a_{kj} a_{ji}) A_l A_m A_n A_o \dots A_t A_M$$

$$+ \sum_{i=1}^{M-3} \sum_{j=i+1}^{M} \sum_{k=i+1}^{M-1} \sum_{l=i+2}^{M} \dots \sum_{M=t+1}^{M} (a_{ij} a_{ji} + a_{kl} a_{lk}) A_m A_n A_o \dots A_t A_M$$

$$+\sum_{i=1}^{M-3} \sum_{j=i+1}^{M} \sum_{k=i+1}^{M-1} \sum_{l=i+2}^{M} \dots \sum_{M=t+1}^{M} (a_{ij} a_{jk} a_{kl} a_{li} + a_{il} a_{lk} a_{kj} a_{ji}) A_m A_n A_o \dots A_t A_M +$$

$$\sum_{i=1}^{M-2} \sum_{j=1}^{M-1} \sum_{j=i+1}^{M} \sum_{l=1}^{M-1} \sum_{m=l+1}^{M-2} \dots \dots \sum_{m=t+1}^{M} (a_{ij} a_{jk} a_{ki} + a_{ik} a_{kj} a_{ji})(a_{lm} a_{m}) A_n A_o \dots A_t A_m +$$

$$\sum_{i=1}^{M-4} \sum_{j=i+1}^{M-1} \sum_{k=j+1}^{M} \sum_{l=1}^{M} \sum_{m=l+1}^{M} \dots \dots \sum_{M=t+1}^{M} (a_{ij} a_{jk} a_{kl} a_{lm} a_{mi} + a_{im} a_{mj} a_{lk} a_{kj} a_{ji}) A_n A_o \dots \dots A_t A_m +$$

$$\sum_{i=1}^{M-3} \sum_{j=i+1}^{M-1} \sum_{k=j+1}^{M} \sum_{l=1}^{M} \sum_{m=l+1}^{M-1} \sum_{n=m+1}^{M} \dots \dots . \sum_{M=t+1}^{M} (a_{ij} a_{jk} a_{ki} + a_{ik} a_{kj} a_{ji})(a_{lm} a_{mn} a_{nl} + a_{ln} a_{nm} a_{ml}) A_o \dots . A_t A_m$$

$$+$$

$$\sum_{i=1}^{M-5} \sum_{j=i+1}^{M-1} \sum_{k=j+1}^{M} \sum_{l=1}^{M-2} \sum_{m=l+1}^{M-1} \sum_{n=m+1}^{M} \dots \dots . \sum_{M=t+1}^{M} (a_{ij} a_{jk} a_{ki} + a_{ik} a_{kj} a_{ji}) +$$
$$(a_{lm} a_{mn} a_{nl} + a_{ln} a_{nm} a_{ml}) A_o \dots A_t A_M$$

$$+\sum_{i=1}^{M-5} \sum_{j=i+1}^{M-1} \sum_{k=j+1}^{M} \sum_{l=1}^{M} \sum_{m=l+1}^{M} \sum_{n=m+1}^{M} \dots \dots . \sum_{M=t+1}^{M} (a_{ij} + a_{jk} a_{kl} a_{lm} a_{mn} a_{nj} + a_{in} a_{nm} a_{ml} a_{lk} a_{kj} a_{ji}) A_o \dots A_t A_M$$

$$+\dots \qquad (8)$$

Step 6. Evaluation and ranking of the alternatives. In this step all alternatives are ranked according to their permanent values calculated in the previous step.

3. Theory/Calculation

The supplier selection problem has received much attention and the problem has been solved through different techniques and methods from a variety of types. Table 1 shows some examples of the approaches adopted to suggest solutions for how to select the most suitable supplier as a single ring of the supply chain.

Tab. 1. Examples of supplier selection methods.

Category	Methodology	Example
MCDM methodologies	AHP / FAHP	Hou & Su [30], F. T. S. Chan, Chan, Ip, & Lau [31], Kilincci & Onal [32], Peng [33]
	ANP / FANP	Buyukozkan & Cifci [34]
	TOPSIS	Boran, Genc, Kurt, & Akay [35]
	DEMATEL	Hsu, Kuo, Chen, & Hu [36]
Mathematical programming	LP	Ng [37], Nosoohi & Mollaverdi [38]
	Multi-objective programming	Narasimhan, Talluri, & Mahapatra [39], Wadhwa & Ravindran [40]
Fuzzy set theory		Aydin Keskin, Ilhan, & Ozkan[41] ;Wang [42]; Kumar, Singh, & Singh [43]
Statistical/ probabilistic	DEA	Ross, Buffa, Dröge, & Carrington [44], Saen [45], Saen [46]
Artificial intelligence	Neural Networks	Celebi & Bayraktar [47]
	Case-based reasoning	Choy & Lee [48], Choy, Lee, Lau, & Choy [49]
	Genetic Algorithm	Yang, Wee, Pai, & Tseng[50]; Yeh & Chuang[51]

Given the need to consider different criteria, it is clear that the supplier selection can be viewed as a MCDM problem. This MCDM problem requires comprehensive methods for an effective problem-solving. As shown in table 1 there are a number of authors which have applied the MCDM techniques including AHP, ANP, TOPSIS and DEMATEL to find a solution for the supplier selection problem. Considering the fact that basic approaches and techniques like the above techniques are simply structured and therefor they eliminate some of the factors which affect the answer to the MCDM problem or take unreal assumptions in solving the problem, many researchers propose approaches which exploit the strengths of different mentioned techniques at once to tackle the problems. Thereupon, using innovative combinations or integrations of different techniques is absolutely common.

In order to find a solution to the problem,a variety of authors have tried to combine two or more techniques through shifting the solution in a specific stage to another technique or using results of one as input of another based on a logical idea. These innovative approaches can both cover the weaknesses of different techniques and pave the way to benefit from the advantages of all involved techniques simultaneously. Regarding the variety of techniques, there can possibly be numerous combinations. Table2 gives some examples of combining two techniques applied by authors to solve the discussing problem: the supplier selection.

Tab. 2. Examples of innovative methods that use combination or integration of two or more techniques to select the best supplier(s).

Combined and integrated techniques	Author(s)
AHP–DEA	Koh, Sevkli, Zaim, Demirbag, & Tatoglu [52], Ramanathan [53]
FAHP – MOLP	Shaw, Shankar, Yadv, & Thakur [54]
ANP–MOP	Demirtas & Ustun [55]
FANP – MOLP	Lin [56]
ANP-TOPSIS / FANP-FTOPSIS	Shyur & Shih [57]; Onut, Kara, & Isik[58], Shirinfar, M. & Hale. H [59]
TOPSIS – DEA	Yuh-Jen[10]
AHP – TOPSIS - DEA	Zeydan, Coplan, & Cobanoglu [60]
Fuzzy set theory – QFD	Bevilacqua, Ciarapica, & Giacchetta [61]; Amin & Razmi [62]
Fuzzy set theory – AHP	Kahraman, Cebeci, & Ulukan [63], F. T. S. Chan & Kumar [64]
ANP – GP	Demirtas & Ustun [55], Aktar Demirtas & Ustun [65]
FANP-FDEMATEL	Yousefi Nejad Attari, M., Bagheri, M.R. & Neishabouri Jami, E. [66]

The content shown in table 2 indicates that one of the common ways of developing more effective methods is combination of two existing MCDM techniques based on a theoretical perspective. The novel technique proposed in the next section is developed using a combination of DEMATEL and GTMA techniques.

3-1. The Proposed Methodology

As Jerry Ho, Tsai, Tzeng, & Fang [67] argued in developing a novel technique to solve MCDM problems, any criterion may impact each other. It is known that many MCDM methodologies do not consider the intercriteria relations. Methodologies like AHP, TOPSIS and VIKOR do not take into account these interactions among criteria despite the fact that they are undeniable and decisive. However, one of the well-known MCDM methodologies which isable to reflect the intercriteria relations in the provided solution is DEMATEL. Therefore the DEMATEL technique could be used to obtain the structure of MCDM problems [67].

Another remarkable point is the inherence of DEMATEL which does not lead to a ranking of alternatives.

The methodology only includes the criteria and acquires the weights to them. Thus, there is a need to use the methodology of DEMATEL as a basis to provide the other methodologies with vital inter criteria relations information. The methodology of GTMA being less used by the researchers despite its efficiency could be the methodology which tracks the results of DEMATEL to come to a final conclusion which is a ranking of different alternatives. On this basis, in the novel technique the DEMATEL technique is used firstly to attain the total relation matrix, as one of the two required starting matrices for GTMA-along with the decision matrix.

The total relation matrix is acquired through implementation of the first 3 steps of DEMATEL (**X**) and encompasses all the intercriteria relations which have been suggested by the DM. Subsequently the problem will be solved through remaining steps of GTMA and once the technique is concluded, we will be able to arrange suppliers from the best to the worst based upon their scores. Thereupon stepwise description of the novel technique is as follows:

Step 1: Generating the direct relation matrix. Measuring the relationship between criteria requires that the comparison scale be designed as 7 levels: 0(no influence), 1(low influence), 2(high influence), 3(very high influence), 4(very high influence). Experts make sets of the pair wise comparisons in terms of influence and direction between criteria, the initial data can be obtained as the direct-relation matrix that is a n x n matrix **A**, in which a_{ij} is denoted as the degree to which the criteria affects the criteria j.

Step 2: Normalizing the direct relation matrix. On the base of the direct – relation matrix A, the normalized direct-relation matrix ***X*** can be obtained through the formulas (1) and (2).

Step 3: Attaining the total relation matrix. Once the normalized direct-relation matrix X is obtained, the total relation matrix ***M*** can be acquired by using formula (3), in which $I$is denoted as the identity matrix.

Step 4: Attaining F_i's. As described earlier, according to the GTMA technique, for each alternative i, the ith row of the decision matrix is replaced by the main diagonal of M, forming F_i.

Step 5: Computing matrix permanents of F_i's. The permanents are denoted by P_i for the i-th alternative.

Step 6: Ranking of the alternatives. The alternatives are arranged according to the descending order of P_i's.

3-2. Case Study

An Iranian industrial company with possession of more than 400 employees (mostly knowledge workers) and one of the major and leading companies in its own field of activity has accompanied the research team in conducting the study. The company provided the case and the information required to conclude the research. The procedure of providing the case and gathering the information was as follows:

At first, the product whose suppliers where to be ranked, was proposed to research team by the company experts in a meeting. Secondly, the criteria on which the suppliers would be evaluated were determined. The final list of the criteria considered is shown in table 3. At the next stage, the experts formed the decision matrix (Table 4) based on the auditing information recorded in a database of suppliers. Finally, the direct relation matrix was generated during a meeting with presence of 3 experts of respected departments. The experts discussed the criteria and determined the direct relation matrix as a unique matrix through consensus. Table 5 demonstrates the final matrix developed by the end of the meeting

Tab. 3. The explanation of criteria applied to compare the different alternatives of suppliers.

C_1	Technology and investment
C_2	Licenses, certifications and the management systems required
C_3	Experience and business reputation
C_4	Human resources
C_5	Financial stability and strength
C_6	Geographical location and ease of access
C_7	Production capacity, capability to manage and plan the orders and flexibility to supply alternating needs

Tab.4. The decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.92	0.63	1.00	1.00	1.00	0.91	1.00
A_2	1.00	0.85	0.92	0.91	0.85	1.00	0.91
A_3	0.92	1.00	0.92	0.74	0.70	1.00	0.91
A_4	0.60	0.70	0.44	0.74	0.63	0.65	0.74
A_5	0.68	0.78	0.28	0.65	0.56	0.74	0.83
A_6	0.44	0.63	0.52	0.39	0.33	0.39	0.48
A_7	0.60	0.70	0.60	0.65	0.48	0.57	0.57
A_8	0.60	0.70	0.60	0.65	0.48	0.57	0.57

Tab. 5. The direct relation matrix set by experts.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	3	2	3	2	0	4
C_2	2	0	3	3	1	0	3
C_3	3	2	0	2	3	1	2
C_4	3	1	4	0	2	0	3
C_5	4	2	3	3	0	3	2
C_6	4	1	1	4	0	0	1
C_7	1	2	2	1	3	1	0

Tab. 6.The total relation matrix [M]developed at the 3rd stage of DEMATEL technique.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0.02	0.28	0.14	0.02	0.02	0.12	0.02
C_2	0.02	0.02	0.02	0.01	0.01	0.02	0.01
C_3	0.03	0.18	0.01	0.02	0.03	0.15	0.03
C_4	0.22	0.46	0.18	0.02	0.11	0.21	0.06
C_5	0.24	0.40	0.14	0.03	0.02	0.23	0.03
C_6	0.03	0.19	0.02	0.01	0.02	0.02	0.01
C_7	0.22	0.53	0.15	0.06	0.11	0.33	0.02

The total relation matrix was input to the GTMA technique along with the decision matrix. Final results are presented and discussed in the next section.

4. Results

Final results of the novel technique are shown in table 7. The technique scores the 2nd alternative as best ranked among the 8 alternatives.

Tab. 7. Results generated by the novel technique.

alternatives	Per	Rank
A1	55.6571	2
A2	58.1184	1
A3	54.7845	3
A4	30.2882	5
A5	28.2667	6
A6	34.4349	4
A7	18.8494	8
A8	26.631	7

5. Discussion and Conclusion

One of the major and affective changes happened across the last 2 decades in business environment is the appearance of supply chain concept. The rings of supply chain are the partners which are called suppliers. A strategic decision made at the early stages of Supply Chain Management (SCM) is supplier selection. Regarding the need to take various factors into account for selecting the best supplier as respond to a strategic requirement, it is clear that the supplier selection can be regarded as a MCDM problem. In this paper, we proposed a new technique combining DEMATEL and GTMA techniques which are two of MCDM techniques and presented a case of supplier selection in an industrial company. First, the results of applying the novel technique indicate that the 2nd candidate is the most appropriate in view of the factors we have considered to evaluate candidates' merit. The number of suppliers that are intended to be selected can be picked from the top of the ranking acquired by the end of solution

Tab. 8. Comparison of the novel technique results with SAW, TOPSIS and VIKOR techniques (common rankings assigned to the same alternatives by all techniques are highlighted).

Alternative	Rank by novel technique	Normalized Per(C_s)	Rank by SAW	Normalized scores	Rank by TOPSIS	Normalized scores	Rank by VIKOR	Normalized scores
A۱	2	0.96	1	1	1	1	1	1
A۲	1	1	2	0.93	2	0.9639879	2	0.9115599
A۳	3	0.94	3	0.86	3	0.7944166	3	0.7137053
A۴	5	0.52	5	0.68	4	0.4560826	4	0.5032615
A۵	6	0.49	6	0.61	6	0.233389	6	0.3547764
A۶	4	0.59	4	0.7	5	0.4365548	5	0.4983375
A۷	8	0.32	8	0.44	8	0.0082483	8	0
A_8	7	0.46	7	0.59	7	0.1682662	7	0.2336682

Next, to evaluate the capability and stability of the proposed technique, a comparison was conducted between the results obtained from the currently used technique (SAW) and two other widely recognized and used MCDM techniques i.e TOPSIS and VIKOR, with the results acquired through application of the new technique (Table 8). To override the effect of different scales of the techniques final indicators, they are normalized. As shown in Table8, the ranks of the alternatives 1 and 2 have been interchanged as the we switch to the novel technique. The noticeable point in comparison between the techniques is the fact that the novel technique scores the top 3 alternatives, remarkably closed. Insofar as the normalized scores (matrix permanents) of the top 3 alternatives lay in an interval with a length of 0.06. While the results scored by SAW, TOPSIS, and VIKOR lay within intervals of respectfully 0.14, 0.21 and 0.29 length. Even the distance between the best and the second best alternative from the SAW technique point of view is more than the one between the best and the third best alternative in the ranking generated by the novel technique.

The next point to magnify is the novel technique scoring the first 3 alternatives distantly in top of the 8 alternatives, while the next 5 alternatives are scored together with short distances, in a different cluster. Figure 1 shows the visual comparison between the results obtained from 4 discussed techniques

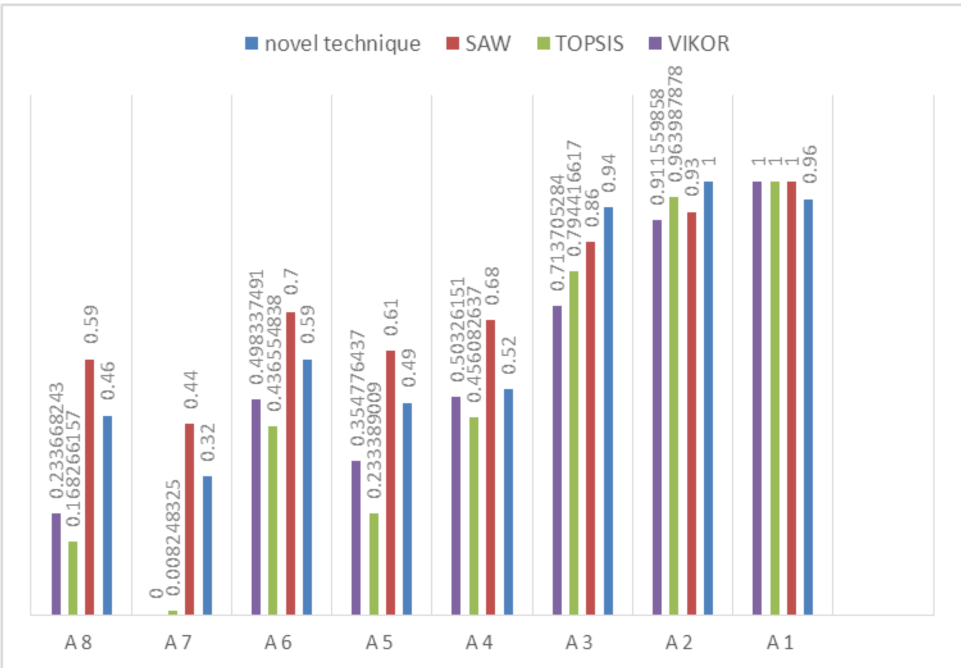

Fig. 1. Visual comparison of the results (normalized final scores), generated by novel technique with those of the currently used technique (SAW), along with TOPSIS and VIKOR

After analyzing the results from all aspects, the experts contributing to the research found the novel technique results more satisfactory and realistic.

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