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RESEARCH PAPER

A Novel Hybrid Strategy to Add Powder Coating to The Product Portfolio (A Real Case Study)

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ABSTRACT
Due to the intensity of competition and economical condition in different countries, a group of manufacturers tried to add new products in their product portfolios in order to gain superiority against their competitors. However, the strategy and the manner of adding the products to the portfolio is one of the biggest challenges in the manufacturing process. As a result, researchers have used a variety of methods to evaluate the alternatives, such as ranking, mathematical optimization and multi criteria decision making. Hybrid methods using multi criteria decision making have gained popularity in recent years. This article uses a novel hybrid strategy using multi criteria decision making in order to find the best alternative. It is concluded that the 'making' alternative is superior to joint venturing and buying alternatives using the net outranking flow index.

KEYWORDS: *Product portfolio; Multi criteria decision making; Net outranking flow; Hybrid method.*

1. Introduction

Recently, according to the intensity of competition in the market, manufacturer's investment for adding new products to their portfolios requires precise evaluation and calculation. Previously, Different methods including ranking, mathematical optimization and Multi Criteria Decision Making (MCDM) were used. However, because of the recent economic conditions, choosing the right option should consider the quantitative and qualitative indices with different weights, which can be done with MCDM methods [1]. MCDM methods are AHP, ANP, DEMATEL, PROMETHEE and hybrid methods.

In the field of renewable energies, there have been numerous studies. Cannemi, García-Melón [2] used ANP for improvement of renewable energy based on choosing the biomass plants. Shiue and Lin [3] employed ANP for evaluation of the optimal recycling strategy. Kabak and Dağdeviren [4] used ANP for ranking of renewable energy resources. Troldborg, Heslop [5] used PROMETHEE in order to assess the technologies in the field of renewable energy sustainability. Mohamadabadi, Tichkowsky [6] utilized PROMETHEE for choosing the best fuel-based vehicles based on renewable and non-renewable evaluation. Cavallaro [7] applied PROMETHEE for assessment of the solar thermal technologies. Kuleli Pak, Albayrak [8] and Datta, Saha [9] used a hybrid method of ANP and TOPSISfor evaluation of renewable energy development and for selection of solar photovoltaic system, respectively. Yeh and Huang [10] used a hybrid method of fuzzy DEMATEL and ANP for selection of wind farm location. Ref. [11] used MCDM method to evaluate stock selection problem algorithms. Ref. [12] applied the MCDM method for decision making in industrial engineering problems. Ref. [13] used the MCDM method in order to find the most suitable supplier using various attributes such as experience and business reputation,

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human resources, and production capacity.

There are a many papers in similar applications, for instance, Bai and Sarkis [14] used DEMATEL in order to assess the business process management. Hu, Lee [15] used DEMATEL for analyzing the performance in computer industry. Horng, Liu [16] applied DEMATEL for assessment of criteria for designing the restaurant space. Büyüközkan and Öztürkcan [17] used a hybrid method of DEMATEL and ANP for selection of six sigma project. Ref. [18] also used ANP for the selection of the suitable six-sigma projects. Chen, Lien [19] applied ANP and DEMATEL for assessment of environment watershed plans. Liou [20] used a hybrid method of DEMATEL and ANP for selection of suitable partners of airline for strategic alliances. Ribeiro Soriano, Jyh-Fu Jeng [21] integrated DEMATEL and ANP for evaluation of customer retention.

Dozic [22] used multi-criteria decision making to identify and classify the problems in aviation industry. He stated that 166 papers published in the period from 2000 to 2018. In order to classify these papers Dozic classify them in four groups and he understood multi-criteria decision-making methods are mostly used in airlines. Sanaei et al. [23] used multi-criteria decision making in order to have a systematic assessment of triticale-based biorefinery strategies. Kiranmaya and Mathirajan [24] proposed an MCDM model by integrating data envelopment analysis (DEA) and balanced scoreboard (BSC) model (called as DEA-BSC model) for projection evaluation and selection (PES) decision in new product portfolio management (NPPM). Ghatreh Samani and Hosseini Motlagh [25] used an enhanced perspective incorporating a two-phase preemptive policy by which the disruption risk is diminished through a hybrid technique using the fuzzy analytic hierarchy process and grey rational analysis for determining supplementary blood facilities, to cooperate in production process and decrease interruptions. Ghatreh Samani and Hosseini Motlagh [26] also used a novel multi-criteria decision-making technique to locate supplementary blood centers so as to prevent disruption to a large extent. In this respect, Grey theory and TOPSIS, a distance-based multiple criteria method was employed to integrate and evaluate the alternative performance for selecting supplementary blood centers. Barak and Mokfi [27] used an MCDM-based framework to evaluate and rank a number of clustering methods.

Considering the lack of sufficient studies in non-governmental manufacturers, in this paper, we considered a non-governmental producer. Here, a hybrid method of DEMATEL-ANP-PROMETHEE implemented in order to show the superior alternative for adding powder coating to the product portfolio of REEF company. In the proposed method, at first, the interrelations between the criteria were studied via the DEMATEL method. Next, the weights which are related to the criteria were computed using ANP, and finally, PROMETHEE was utilized to rank the alternatives.

2. Experimental Procedure

The network diagram for adding powder coating to the product portfolio of REEF company used in this study is shown in Figure 1.

Criterion				
Capability	Strategy	Market	Technology	Environment
Technology position for the manufacturer	Time to obtain the technology	Uncertainty about commercialization	Technology life span	Competitive effect of the technology
R&D experiences for production	Effects of organization resources	The level of credits from the technology	Technology development cost	Government support for R&D cooperation
Relative capability of manufacturer for the technology	The importance of technology for the manufacturer	Size of the market	Technology relation with other products	Technology acquisition risk and availability of exterior resource
The level of investment and financial risk	The necessity of technology acquisition for	The intensity of competition	Technology complexity	Lack of confidence and environmental

	the manufacturer			complexity
The level of familiarity of the manufacturer with the technology		Manufacturer familiarity about market condition and the required technology	Technology adaptation with manufacturer strengths	Political, legal and executive factors as well as economic sanctions
Manufacturer experiences about the manner of technical knowledge acquisition		The portion of potential market	The elasticity of variation in production technology	
			Ease of copying	

Alternative		
Making	Joint Venture	Buying

Fig. 1. The network diagram of the present study

2.1. Dematel

DEMATEL is a structural modeling tool that is utilized in order to show the cause and effect relationship among various criteria [28]. The DEMATEL method builds the interrelations between criteria in order to make a Network Relation Map (NRM) [29]. The 5 steps of DEMATEL procedure aRE explained in the following:

Step 1: In this step, at first, the experts' opinion is gathered and the average direct relation matrix A IS calculated. Next, H experts are asked to consider the level of direct influence between each of the two factors, denoted as X_{ij}, based on pairwise comparison. Each experts' opinion resulted in an $n \times n$ matrix, as $X^k = [x_{ij}^k]$, where *k* is the number of experts that took part in the process ($1 \leq k \leq H$). The average direct relation matrix A, is obtained from the average of the identical factors in H direct matrices of the respondents (Eq. 1).

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Step 2: In this step, the normalized initial direct relation matrix is calculated. This matrix is $D = [d_{ij}]$, which is the multiplication of matrix A and S (Eq. 2). The value of each element in matrix X is between 0 and 1.

$$X = S.A \quad (2)$$

Where:

$$s = \min\left[\frac{1}{\max_i \sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n}|a_{ij}|}\right] \quad (3)$$

Step 3: In step 3, the total relation matrix T is calculated by using Eq. 4. In this equation, I is an $n \times n$ identity matrix. The element t_{ij} shows the indirect influences that factor i has on factor j. Matrix T calculates the total relationship between each pair of system factors.

$$T = X(I - X)^{-1} \quad (4)$$

Step 4: here, the sum of rows (r) and columns (c) of the matrix T is calculated. The vector r and c are calculated using Eq. 5 and Eq. 6.

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

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

Where r_i is the sum of the i^{th} row in matrix T. The value of r_i indicates the total effects, both direct and indirect, which factor I has on the other factors. c_j is the sum of the j^{th} column in the matrix T. Again, the value of c_j shows total effects, both direct and indirect, received by a factor j given by other factors.

Step 5: In this step a threshold value "p" is set on the basis of the expert opinion. Then, the Network Relation Map (NRM) is obtained. NRM is obtained by mapping all of the coordinate sets of $(r_i + c_i, r_i - c_i)$ in order to visualize the complex interrelationship and to provide information for understanding which factor is the most important one, and how it influences the affected factors [28] and [30].

2.2. ANP

ANP is a developed form of AHP, which was presented by Saaty [31]. ANP is normally used to build an un-weighted super matrix in order to devote importance weights to factors. However, one limitation in ANP is that the results from the questionnaire is difficult to understand. As a result, NRM and total influence matrix, T, which is obtained from DEMATEL method, will be used for revealing the interrelations among factors. The process of ANP in this article is presented in the following:

Step 1: In this step, a super matrix is obtained by comparing the criteria in the whole system. The normal form of the super matrix is shown in Eq. 7:

$$W = \begin{matrix} & \begin{matrix} c_1 & c_2 & c_3 & c_4 \end{matrix} \\ \begin{matrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{matrix} & \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{12} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nn} \end{bmatrix} \end{matrix} \quad (7)$$

Where W_{ij} is the eigenvector of the effect of the elements in j^{th} cluster in comparison with the i^{th} cluster, C_n is the n^{th} cluster, and e_{nm} is the m^{th} element in the n^{th} cluster.

Step 2: In this step, the super matrix, which was weighted in the previous section, is attained by multiplying the normalized matrix which is calculated using DEMATEL method. Then, a new matrix is derived from DEMATEL method by using the total-influence matrix T and a threshold value. It should be noted that the values of the clusters in matrix T are changed to zero if their values are less than the threshold. Finally, a novel matrix with p-cut is obtained which is called the p-cut total influence matrix T_α (Eq. 8).

$$T_\alpha = \begin{bmatrix} t_{11}^\alpha & \cdots & t_{1j}^\alpha & \cdots & t_{1n}^\alpha \\ \vdots & & \vdots & & \vdots \\ t_{i1}^\alpha & \cdots & t_{ij}^\alpha & \cdots & t_{in}^\alpha \\ \vdots & & \vdots & & \vdots \\ t_{n1}^\alpha & \cdots & t_{nj}^\alpha & \cdots & t_{nn}^\alpha \end{bmatrix} \quad (8)$$

T_α should be normalized using Eq. 9.

$$d_i = \sum_{j=1}^{n} t_{ij}^\alpha \quad (9)$$

Next, the normalized total-influence matrix T_s is obtained using Eq. 10.

$$T_s = \begin{bmatrix} t_{11}^\alpha/d_1 & \cdots & t_{1j}^\alpha/d_1 & \cdots & t_{1n}^\alpha/d_1 \\ \vdots & & \vdots & & \vdots \\ t_{i1}^\alpha/d_2 & \cdots & t_{ij}^\alpha/d_2 & \cdots & t_{in}^\alpha/d_2 \\ \vdots & & \vdots & & \vdots \\ t_{n1}^\alpha/d_3 & \cdots & t_{nj}^\alpha/d_3 & \cdots & t_{nn}^\alpha/d_3 \end{bmatrix} = \begin{bmatrix} t_{11}^s & \cdots & t_{1j}^s & \cdots & t_{1n}^s \\ \vdots & & \vdots & & \vdots \\ t_{i1}^s & \cdots & t_{ij}^s & \cdots & t_{in}^s \\ \vdots & & \vdots & & \vdots \\ t_{n1}^s & \cdots & t_{nj}^s & \cdots & t_{nn}^s \end{bmatrix} \quad (10)$$

Finally, the weighted super matrix W_w is calculated with Eq. 11.

$$W_w = \begin{bmatrix} t_{11}^s \times W_{11} & t_{21}^s \times W_{12} & \cdots & \cdots & t_{n1}^s \times W_{1n} \\ t_{12}^s \times W_{21} & t_{22}^s \times W_{22} & \vdots & & \vdots \\ \vdots & \cdots & t_{ji}^s \times W_{ij} & \cdots & t_{ni}^s \times W_{in} \\ \vdots & & \vdots & & \vdots \\ t_{1n}^s \times W_{n1} & t_{21}^s \times W_{n2} & \cdots & \cdots & t_{nn}^s \times W_{nn} \end{bmatrix} \quad (11)$$

Where T_s is the normalized p-cut total-influence matrix and W is the un-weighted super matrix. Eq.11 reveals the influence level values which is used as the basis of the normalization in order to determine the weighted super matrix.

Step 3: In this stage, the weighted super matrix is limited by raising it to a large power k_s (Eq. 12), this process will be accomplished until the super matrix converges and the ANP weights are obtained.

$$\lim_{k\to\infty} W_w^k \quad (12)$$

2.3. PROMETHEE

After obtaining the weights of the criteria via ANP, PROMETHEE method is used in order to specify the best strategy. PROMETHEE was first introduced by Brans [32], and it is one of the most famous multi-criteria decision making techniques. PROMETHEE is consists of 6 different methods including PROMETHEE I, II, III, IV, V and VI [33]. In this study, PROMETHEE II is utilized due to the matching conditions of it with the considered problem. The steps used in PROMETHEE are:

Step 1. In this step, deviations are obtained based on the pairwise comparison (Eq. 13).

$$d_j(a,b) = g_j(a) \quad g_j(b) \tag{13}$$

Where $d_j(a,b)$ is the difference of the evaluation of the alternatives $g_j(a)$ and $g_j(b)$ with respect to j criterion.

Step 2: In this step, the preference of alternative "a" with regard to alternative "b" or $P_j(a,b)$ is calculated using the chosen preference functions (Eq. 14).

$$P_j(a,b) = F_j\left[d_j(a,b)\right] \quad j = 1, \dots, k \tag{14}$$

Step 3: In this step, Eq. 15 is employed in order to calculate the overall preference indices.

$$\forall a, b \in A, \qquad \Pi(a,b) = \sum_{j=1}^{k} P_j(a,b) W_j \tag{15}$$

Where $\Pi(a,b)$ is the weighted sum of p(a,b) for each criterion and W_j is the weight of the j^{th} criterion.

Step 4: In this step, positive outranking flow $\phi^+(a)$ and $\phi^-(a)$ are computed using Eq. 16.

$$\phi^+(a) = \frac{1}{n-1}\sum_{x \in A} \Pi(a,x) \qquad \phi^-(a) = \frac{1}{n-1}\sum_{x \in A} \Pi(x,a) \tag{16}$$

Step 5: Finally, the net outranking flows ($\phi(a)$) for each alternative are calculated using Eq. 17.

$$\phi(a) = \phi^+(a) - \phi^-(a) \tag{17}$$

3. Results and Discussion

The goal of this research is the selection of the proper method in order to add powder coating to the product portfolio of REEF Company using DEMATEL-ANP-PROMETHEE hybrid method.

3.1. Alternatives ranking using the proposed method

At first, the factors that have an influence on the alternatives are identified. Second, the relationship between these factors are highlighted. Third, the weights are calculated using the obtained relationships and ANP. Finally, the alternatives are ranked using PROMETHEE.

3.1.1. Determination of the relationships using DEMATEL

In this section, the relationships between the criteria are determined using DEMATEL. Subsequently, the network structure is formed in order to determine the criteria weights using the threshold value of 0.104. Table 1 shows the T matrix for criteria.

Tab. 1. T matrix for criteria

	Capability	Strategy	Market	Technology	Environment
Capability	0.007	0.301	0.356	0.419	0.265
Strategy	0.008	0.007	0.302	0.302	0.180
Market	0.006	0.008	0.006	0.127	0.117
Technology	0.005	0.007	0.014	0.006	0.090
Environment	0.008	0.012	0.017	0.021	0.006

It is evident that the relationships that have a value above the threshold are used for the ANP segment. Similarly, these steps are accomplished for all of the criteria. The T matrix for the remaining criteria are shown is Tables 2-6.

Tab. 2. T matrix for the capability criteria

	Technology position for the manufacturer	R&D experiences for production	Relative capability of manufacturer for the technology	The level of investment and financial risk	The level of familiarity of the manufacturer with the technology	Manufacturer experiences about the manner of technical knowledge acquisition
Technology position for the manufacturer	0.007	0.177	0.268	0.177	0.379	0.422
R&D experiences for production	0.010	0.007	0.177	0.143	0.263	0.311
Relative	0.007	0.011	0.007	0.175	0.185	0.266

	Technology position for the manufacturer	R&D experiences for production	Relative capability of manufacturer for the technology	The level of investment and financial risk	The level of familiarity of the manufacturer with the technology	Manufacturer experiences about the manner of technical knowledge acquisition
capability of manufacturer for the technology						
The level of investment and financial risk	0.011	0.013	0.013	0.007	0.240	0.195
The level of familiarity of the manufacturer with the technology	0.005	0.007	0.010	0.008	0.007	0.207
Manufacturer experiences about the manner of technical knowledge acquisition	0.004	0.006	0.007	0.009	0.010	0.007

Tab. 3. T matrix for the strategy criteria

	Time to obtain technology	Effects of organization resources	The importance of technology for the manufacturer	The necessity of technology acquisition for the manufacturer
Time to obtain technology	0.006	0.340	0.427	0.524
Effects of organization resources	0.008	0.006	0.262	0.384
The importance of technology for the manufacturer	0.005	0.009	0.006	0.182
The necessity of technology acquisition for the manufacturer	0.005	0.006	0.012	0.006

Tab. 4. T matrix for the market criteria

	Uncertainty about commercialization	The level of credits from the technology	Size of the market	The intensity of competition	Manufacturer familiarity with the market condition and the required technology	The portion of potential market
Uncertainty about commercialization	0.006	0.248	0.247	0.278	0.277	0.381
The level of credits from the technology	0.006	0.006	0.131	0.187	0.181	0.212
Size of the market	0.007	0.013	0.006	0.219	0.245	0.309
The intensity of competition	0.006	0.009	0.007	0.011	0.006	0.133
Manufacturer familiarity with the market condition and the required technology	0.006	0.009	0.007	0.011	0.006	0.133

	Uncertainty about commercialization	The level of credits from the technology	Size of the market	The intensity of competition	Manufacturer familiarity with the market condition and the required technology	The portion of potential market
The portion of potential market	0.004	0.007	0.005	0.008	0.010	0.005

Tab. 5. T matrix for the technology criteria

	Technology life span	Technology development cost	Technology relation with the other products	Technology complexity	Technology adaptation with manufacturer strengths	The flexibility of variation in technology	Ease of copying
Technology life span	0.007	0.078	0.097	0.214	0.091	0.201	0.237
Technology development cost	0.020	0.007	0.200	0.261	0.067	0.162	0.370
Technology relation with the other products	0.014	0.008	0.007	0.050	0.049	0.118	0.121
Technology complexity	0.009	0.009	0.028	0.008	0.038	0.252	0.315
Technology adaptation with manufacturer strengths	0.014	0.021	0.027	0.038	0.006	0.059	0.133
The elasticity of variation in production technology	0.009	0.014	0.015	0.010	0.023	0.008	0.255
Ease of copying	0.009	0.004	0.013	0.007	0.010	0.008	0.008

Tab. 6. T matrix for the environment criteria

	Competitive effect of the technology	Government support for R&D cooperation	Technology acquisition risk and availability of external resources	Lack of confidence and environmental complexity	Political, legal and executive factors as well as economic sanctions
Competitive effect of the technology	0.031	0.254	0.369	0.562	0.228
Government support for R&D cooperation	0.038	0.028	0.093	0.160	0.105
Technology acquisition risk and availability of external resources	0.032	0.108	0.031	0.363	0.161
Lack of confidence and	0.021	0.064	0.034	0.032	0.121

	Competitive effect of the technology	Government support for R&D cooperation	Technology acquisition risk and availability of external resources	Lack of confidence and environmental complexity	Political, legal and executive factors as well as economic sanctions
environmental complexity					
Political, legal and executive factors as well as economic sanctions	0.054	0.094	0.075	0.105	0.032

3.1.2. Determination of the weights of the criteria using ANP

In order to calculate the weights of the criteria, a pairwise comparison questionnaire was designed. With the help of the experts, pairwise comparison was accomplished. After that, the pairwise comparisons were added to the Super Decision software and the data were analyzed. The weights of the criteria are given in Table 7.

Tab. 7. The weights of the criteria using ANP

Major Criterion	Weight of the major criterion	Criterion	Weight	Final weight
Strategy	0.233	Time to obtain technology	0.358	0.083
		Effects of organization resources	0.369	0.086
		The importance of technology for the manufacturer	0.220	0.051
		The necessity of technology acquisition for the manufacturer	0.053	0.012
Market	0.076	Uncertainty about commercialization	0.272	0.021
		The level of credits from the technology	0.182	0.014
		Size of the market	0.237	0.018
		The intensity of competition	0.169	0.013
		Manufacturer familiarity with the market condition and the required technology	0.100	0.008
		The portion of potential market	0.038	0.003
Capability	0.599	Technology position for the manufacturer	0.242	0.145
		R&D experiences for production	0.215	0.129
		Relative capability of manufacturer for the technology	0.216	0.129
		The level of investment and financial risk	0.166	0.099
		The level of familiarity of the manufacturer with the technology	0.118	0.071
		Manufacturer experiences with the manner of technical knowledge acquisition	0.042	0.025
Environment	0.047	Competitive effect of the technology	0.237	0.011
		Government support for R&D cooperation	0.175	0.008
		Technology acquisition risk and availability of external resources	0.231	0.011
		Lack of confidence and environmental complexity	0.178	0.008
		Political, legal and executive factors as well as economic sanctions	0.179	0.008
Technology	0.046	Technology life span	0.160	0.007
		Technology development cost	0.237	0.011
		Technology relation with the other products	0.122	0.006
		Technology complexity	0.171	0.008
		Technology adaptation with manufacturer strengths	0.070	0.003
		The elasticity of variation in production technology	0.187	0.009
		The ease of copying	0.054	0.002

3.1.3. The ranking of the alternatives using PROMETHEE

Table 8 reveals the outranking flows for three different alternatives including making, joint venture and buying alternatives.

Tab. 8. The outranking flows for each alternative

	Alternative	$\emptyset$	$\emptyset^+$	$\emptyset^-$
1	Making	0.293	0.509	0.216
2	Joint venture	0.170	0.416	0.246
3	Buying	- 0.463	0.117	0.058

Table 8 shows that the making alternative is superior to joint venture and buying alternatives. The net outranking flow ($\emptyset$) for the making alternative is 0.216 which is more than 0.170 and –0.463 for joint venturing and buying alternatives, respectively. This means that among all of the alternatives for adding powder coating to the product portfolio of the REEF Company, the making alternative is the preferable choice.

4. Conclusion

In the new decade, investment in new products requires a precise evaluation. This means that the manufacturers need to choose the best approach to make advancements in their company without losing resources. As a result, different methods of decision making are utilized in order to find the superior alternative among the choices encountered by the manufacturers. There are numerous methods of decision making. The MCDM techniques including AHP, ANP, DEMATEL, PROMETHEE and the hybrid mix of these methods have recently become prevalent. In this research, a hybrid DEMATEL-ANP-PROMETHEE method was utilized in order to reveal the superior alternative for the purpose of adding powder coating to the product portfolio of REEF Company. Three alternatives including, making, joint venturing and buying were considered, and the proposed method shows that the "making" alternative is superior to other options.

References

[1]. Karsak, E.E. and C.O. Özogul, *An integrated decision making approach for ERP system selection*. Expert systems with Applications, Vol. 36, No. 1, (2009), pp. 660-667.

[2]. Cannemi, M., et al., *Modeling decision making as a support tool for policy making on renewable energy development*. Energy Policy, Vol. 67, (2014), pp. 127-137.

[3]. Shiue, Y.-C. and C.-Y. Lin, *Applying analytic network process to evaluate the optimal recycling strategy in upstream of solar energy industry*. Energy and Buildings, Vol. 54, (2012), pp. 266-277.

[4]. Kabak, M. and M. Dağdeviren, *Prioritization of renewable energy sources for Turkey by using a hybrid MCDM methodology*. Energy Conversion and Management, Vol. 79, (2014), pp. 25-33.

[5]. Troldborg, M., S. Heslop, and R.L. Hough, *Assessing the sustainability of renewable energy technologies using multi-criteria analysis: Suitability of approach for national-scale assessments and associated uncertainties*. Renewable and Sustainable Energy Reviews, Vol. 39, (2014), pp. 1173-1184.

[6]. Mohamadabadi, H.S., G. Tichkowsky, and A. Kumar, *Development of a multi-criteria assessment model for ranking of renewable and non-renewable transportation fuel vehicles*. Energy, Vol. 34, No. 1, (2009), pp. 112-125.

[7]. Cavallaro, F., *Multi-criteria decision aid to assess concentrated solar thermal technologies*. Renewable Energy, Vol. 34, No. 7, (2009), pp. 1678-1685.

[8]. Kuleli Pak, B., Y.E. Albayrak, and Y.C. Erensal, *Renewable energy perspective for Turkey using sustainability indicators*. International Journal of Computational Intelligence Systems, Vol. 8, No. 1, (2015), pp. 187-197.

[9]. Datta, A., et al., *Anti-islanding selection for grid-connected solar photovoltaic system applications: A MCDM based distance approach*. Solar Energy, Vol.

110, (2014), pp. 519-532.

[10]. Yeh, T.-M. and Y.-L. Huang, *Factors in determining wind farm location: Integrating GQM, fuzzy DEMATEL, and ANP*. Renewable Energy, Vol. 66, (2014), pp. 159-169.

[11]. Makui, A. and E. Mohammadi, *A MCDM-based approach using UTA-STRAR method to discover behavioral aspects in stock selection problem*. International Journal of Industrial Engineering & Production Research, Vol. 30, No. 1, (2019), pp. 93-103.

[12]. Yousefi Nejad Attari, M., M. Bagheri, and E. Neishabouri, *A decision making model for outsourcing of manufacturing activities by ANP and DEMATEL under fuzzy environment*. International Journal of Industrial Engineering & Production Research, Vol. 3, No. 9, (2012).

[13]. Kashef Khanmohammadi, E., *A novel technique to solve the supplier selection problem: combination of decision making trial and evaluation laboratory and graph theory and matrix approach methods*. International Journal of Industrial Engineering & Production Research, Vol. 25, No. 2, (2014), pp. 103-114.

[14]. Bai, C. and J. Sarkis, *A grey-based DEMATEL model for evaluating business process management critical success factors*. International Journal of Production Economics, Vol. 146, No. 1, (2013), pp. 281-292.

[15]. Hu, H.-Y., et al., *Using BPNN and DEMATEL to modify importance–performance analysis model–A study of the computer industry*. Expert Systems with Applications, Vol. 36, No. 6, (2009), pp. 9969-9979.

[16]. Horng, J.-S., et al., *Creativity as a critical criterion for future restaurant space design: Developing a novel model with DEMATEL application*. International Journal of Hospitality Management, Vol. 33, (2013), pp. 96-105.

[17]. Büyüközkan, G. and D. Öztürkcan, *An integrated analytic approach for Six Sigma project selection*. Expert Systems with Applications, Vol. 37, No. 8, (2010), pp. 5835-5847.

[18]. Saghaei, H. and H. Didehkhani, *Application of Analytic Network Process in Selection of Six-Sigma Projects*. International Journal of Industrial Engineering & Production Research, Vol. 20, No. 4, (2010), pp. 157-164.

[19]. Chen, Y.-C., H.-P. Lien, and G.-H. Tzeng, *Measures and evaluation for environment watershed plans using a novel hybrid MCDM model*. Expert systems with applications, Vol. 37, No. 2, (2010), pp. 926-938.

[20]. Liou, J.J., *Developing an integrated model for the selection of strategic alliance partners in the airline industry*. Knowledge-Based Systems, Vol. 28, (2012), pp. 59-67.

[21]. Ribeiro Soriano, D., D. Jyh-Fu Jeng, and T. Bailey, *Assessing customer retention strategies in mobile telecommunications: Hybrid MCDM approach*. Management Decision, Vol. 50, No. 9, (2012), pp. 1570-1595.

[22]. Dožić, S., *Multi-criteria decision making methods: Application in the aviation industry*. Journal of Air Transport Management, Vol. 79, (2019), p. 101683.

[23]. Sanaei, S., V. Chambost, and P.R. Stuart, *Systematic assessment of triticale-based biorefinery strategies: sustainability assessment using multi-criteria decision-making (MCDM)*. Biofuels, Bioproducts and Biorefining, Vol. 12, (2018), pp. S73-S86.

[24]. Kiranmayi, P. and M. Mathirajan, *An Integrated Multicriteria Decision-Making Model for New Product Portfolio Management*. Big Data Analytics Using Multiple Criteria Decision-Making Models, (2017), p. 315.

[25]. Ghatreh Samani, M. and S.-M. Hosseini-Motlagh, *Evaluation and Selection of Most Preferable Supplementary Blood Centers in The Case of Tehran.* International Journal of Hospital Research, Vol. 7, No. 4, (2018), pp. 81-101.

[26]. Samani, M.R.G. and S.-M. Hosseini-Motlagh, *An enhanced procedure for managing blood supply chain under disruptions and uncertainties.* Annals of Operations Research, Vol. 283, No. 1, (2019), pp. 1413-1462.

[27]. Barak, S. and T. Mokfi, *Evaluation and selection of clustering methods using a hybrid group MCDM.* Expert Systems with Applications, Vol. 138, (2019), pp. 112817.

[28]. Yang, J.L. and G.-H. Tzeng, *An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method.* Expert Systems with Applications, Vol. 38, No. 3, (2011), pp. 1417-1424.

[29]. Yang, Y.-P.O., et al., *A novel hybrid MCDM model combined with DEMATEL and ANP with applications.* International journal of operations research, Vol. 5, No. 3, (2008), pp. 160-168.

[30]. Tzeng, G.-H., C.-H. Chiang, and C.-W. Li, *Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL.* Expert systems with Applications, Vol. 32, No. 4, (2007), pp. 1028-1044.

[31]. Saaty, T.L., *Decision making with dependence and feedback: The analytic network process*. Vol. 4922. (1996): RWS publications Pittsburgh.

[32]. Brans, J.P.*), Lingenierie de la decision. Methode PROMETHEE. In R. Nadeau & M. Landry (Eds.), Laide a la decision: Nature, instrument set perspectives davenir* (1982), pp. 183-214.

[33] Vinckle, J.P. and P. Brans, *A preference ranking organization method. The PROMETHEE method for MCDM.* Management Science, Vol. 31, (1985), pp. 641-656.

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