FUZZY OPTIMIZATION AND MODELLING 2(2) (2021) 22-33

E-ISNN: 2676-7007

Contents lists available at FOMJ

Fuzzy Optimization and Modelling

Journal homepage: http://fomj.qaemiau.ac.ir/

Paper Type: Research Paper

Considering the Criteria interdependency in the Matrix Approach to Robustness Analysis with Applying Fuzzy ANP

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A R T I C L E I N F O

Article history:
Received 31 May 2021
Revised 15 July 2021
Accepted 20 July 2021
Available online 25 July 2021

Keywords:
Matrix Approach
Robustness Analysis
Fuzzy ANP
Strategy Selection

A B S T R A C T

Choosing the appropriate strategy is the most vital decision for an organization. The real-world situation, comprising increasing criteria and alternatives; the criteria interdependency; environmental changes affecting the structure of the organization; the vagueness of the verbal judgments; and Increasing uncertainty about possible futures, forces the decision-makers to consider these two important elements, complexity and uncertainty, in their decision-making approach. While all of the most widely known approaches – the classic, scenario, MCDM, and robustness analysis approaches – have some weaknesses related to either complexity or uncertainty, the approach purposed in this study can overcome them, combining the matrix approach to the robustness analysis (MARA) with the fuzzy ANP method. This approach deals with the environmental uncertainty by reviewing the performance of the strategies among the alternative futures, the uncertainty related to the preference model of the human decision-maker (uncertain judgements) by using fuzzy set theory, specifically Chang's extent analysis method, considers desired number of scenarios, criteria and options, and collects experts' judgments in an appropriate time, emphasizing interdependences among criteria. The proposed approach is applied to a real-world problem in the automotive industry of Iran and the results are compared with the previous studies.

1. Introduction

Having a significant share of more than %10 of the total value added of the industrial sector and more than a half-million workforces, The automotive industry possesses the most significant sector after the oil and petroleum sectors in Iran [17]. Despite being strategic, this industry has faced so many problems, especially during the last decade. Theoretically speaking, it can be said that many of these problems have been caused

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DOI: 10.30495/FOMJ.2021.1932066.1029

because of poor decisions made by the top-level decision-makers, specifically about the long term ones, like choosing the appropriate strategy while it is the most vital decision for an organization [19]. Decision-making, the process of finding the best option from a range of available options [30], in complex and uncertain environments, generally requires dealing with problems in which descriptions of the environment and decision elements, as well as judgments, are highly subjective, vague and/or imprecise by nature [2]. Thus, facing this situation, in which on the one hand, because of increasing criteria and alternatives, it is almost impossible for decision-makers to make an appropriate decision [16], and on the other hand, because of environmental changes affecting the structure of the organization [1]; and Increasing uncertainty about possible futures [11], it is almost possible to encounter disappointing outcomes [41], forces decision-makers to consider this two essential elements, complexity and uncertainty, in their decision-making approach.

All the most widely known and used approaches used by researchers to select the best option, or strategy, have some weaknesses related to either complexity or uncertainty [35]. The classic approach, SWOT and QSPM, cannot consider both uncertainty key aspects: the future uncertainty and vague data [43]. The scenario planning approach, because of the human capacity constraints [22], is not able to consider a large number of options and scenarios, while In the cases where multiple variables can make significant changes in the future environment, the constraint of future scenarios is considered as a significant weakness [35]. Despite combining quantitative and qualitative criteria, concerning opinions of several decision-makers, as well as expressing the human thinking mathematically [8] and the fuzzy characters of the parameters [44], the next approach, MCDM developed to solve large scale problems [15], fails to formulate the probable futures since it uses the present information and judgments to collect the data [34]. Finally, the last approach, Robustness Analysis (RA), is able to a great extent to deal with both uncertainty and complexity. In the RA approach, a decision is made which leads to more reasonable and less adverse outcomes among different futures [29], and this is the most important feature of RA [26]. Moreover, to address uncertainty [2], using fuzzy set theory makes this approach able to cope with vague data and uncertain judgment [23]. Furthermore, the RA approach covers one important aspect of the complexity related to the number of scenarios, options, and criteria in an ideal time [33]. Still, it doesn't consider another aspect of the complexity, the criteria interdependency [24] or network structure [25]. In such a complex situation, according to the literature [21], the most addressed solution is the analytic network process (ANP) [32] which is capable of modelling the complex structure [13].

As it systematically evaluates all the relationships including potential interactions, interdependences, and feedbacks in a decision-making process [23], the ANP method, Unlike the well-known method AHP, does not require the hierarchical relation [31] but a network of elements [20]. In this method, pairwise comparison judgments can determine relevant importance and dominance among the elements and components [38]. The pairwise comparison process assumes that the decision-maker can compare any two elements E_i and E_j, and provide a numerical value of the ratio of their importance. In many cases, however, the preference model of the human decision-maker is uncertain, and it is relatively difficult for them to provide exact numerical values for the comparison ratios [23]. So, as used in the situation in which the decision-making process faces unclear and equivocal human linguistic utterances [42], the fuzzy set theory approach is an inevitable tool for this problem [12]. Hence, in this study, we are going to propose an extended methodology that combines the Matrix Approach to Robustness Analysis (MARA) with Fuzzy Analytic Network Process (FANP) to cope with these two prenominated elements: uncertainty and complexity. For this purpose, our methodology is explained in the next section in detail. In Section 3, our methodology is applied to a real-world problem in the automotive industry of Iran, and the final section is devoted to the conclusions.

2. Methodology

According to the first work of Sorourkhah et al. [34], which introduced MARA, we need first to identify the strategies. In this context, the main strategies MS_i, $i=1,\dots,r$, are specified as a result of choosing a certain number of predefined sub-strategies S_j, $j=1,\dots, m$. More exactly, the dependence relationships are illustrated as follows:

$$MS_i = S_{j1} S_{j2} \ldots S_{ji},\ i = 1, \ldots, r, \tag{1}$$

showing that the main strategy MS_i is a hybridization of the sub-strategies S_{j1}, $S_{j2}, \ldots, S_{ji}$. The second step is to define the future scenarios. The scenarios are defined based on probable situations of the PESTEL factors (political, economic, social, technological, environmental and legal) as ordered in the 6-tuples $Sn_i = (P_i, Ec_i, So_i, T_i, En_i, L_i),\ i= 1,2,\ldots,q$. The general form of scenario components is presented in Table 1. Furthermore, the scenarios matrix M which is of the order $6\times q$ can be defined by setting the 6-tuples Sn_i as its ith column. More precisely,

$$M = [Sn_1,\ Sn_2, \ldots,\ Sn_q]. \tag{2}$$

Table 1. General form of the scenario components

Factors	Indicators	Situations
Political	P_i	$i=1,2,\ldots,p$
Economic	Ec_i	$i=1,2,\ldots,c$
Social	So_i	$i=1,2,\ldots,s$
Technological	T_i	$i=1,2,\ldots,t$
Environmental	En_i	$i=1,2,\ldots,n$
Legal	L_i	$i=1,2,\ldots,l$

The next step is to determine strategies favorability and non-favorability conditions. In this context, for the strategy Sj, two ordered 6-tuples Sj^+ and Sj^- are defined to refer to its favorability and non-favorability conditions, respectively. The elements of the two vectors contain the different states of the indicators displayed in Table 1, determined by decision-makers. Afterwards, the strategic condition matrix A of the order 6×2m can be defined as follows:

$$A = [S_1^{+},\ S_1^{-},\ S_2^{+},\ S_2^{-}, \ldots,\ S_m^{+},\ S_m^{-}]. \tag{3}$$

For the next step, Sorourkhah et al. [33] firstly introduced the weighted-robustness analysis approach [33] and afterwards (2019), they proposed the fuzzy-weighted approach [35] to solve some of the RA approach weaknesses, but as mentioned above, none of them is able to consider the complex situation involved interactions among criteria. Therefore, in this study, we use FANP to come up with a more reliable solution. It is worth noting that as the output numbers in the comparison matrices are definite, we cannot use these matrices in the cases in which the output numbers face ambiguity [42]. Thus, we apply Chang’s extent analysis method [6] steps of which are summarized as follows:

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object sets, and $G = \{g_1, g_2, \ldots, g_n\}$ be a goal set. Each object is taken, and an extent analysis for each goal, g_i, is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following sings:

$$M_{gi}^{1}, M_{gi}^{2}, \ldots, M_{gi}^{m},\quad i = 1, 2, \ldots, n, \tag{4}$$

where all the M_{gi}^{j} $(j = 1, 2, \ldots, m)$ are triangular fuzzy numbers (TFNs). A triangular fuzzy number $\tilde{M}$ which is shown in Figure 1, is represented by (l, m, u). The parameters l, m, and u refer to the smallest possible value, the most promising value, and the largest possible value, respectively. Each TFN is denoted by linear representation on its right and left sides such that its membership function μ can be defined as in equation (5):

$$\mu\left(\frac{x}{M}\right)=\begin{cases}0, & x<l\\ \frac{x-l}{m-l}, & l\le x\le m\\ \frac{u-x}{u-m}, & m\le x\le u\\ 0, & x>u\end{cases} \quad (5)$$

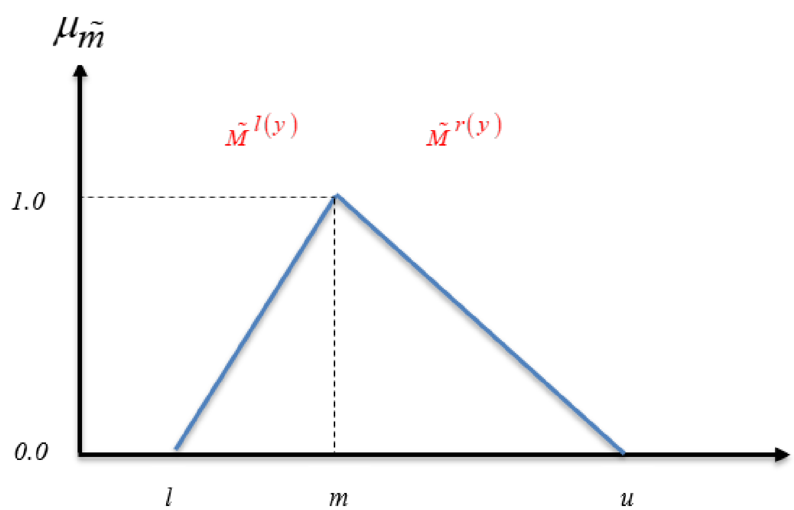

Figure 1. A triangular fuzzy number

The steps of Chang's extent analysis can be given as in the following:

- Step 1, The value of fuzzy synthetic extent with respect to the *i*th object is defined as

$$S_i=\sum_{j=1}^{m} M_{gi}^{j} \otimes\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}. \quad (6)$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$ conduct the fuzzy addition operation of the extent of *m* analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{gi}^{j}=\left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (7)$$

and to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$, the fuzzy addition operation of M_{gi}^{j}, $j=(1,2,\ldots,m)$ values are processed as:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}=\left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \quad (8)$$

and then compute the inverse of the matrix $\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}$ such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right). \tag{9}$$

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

$$V(M_2 \geq M_1) = \sup_{y \geq x}\left[\min(\mu_{M_1}(x), \mu_{M_2}(y))\right] \tag{10}$$

and can also be represented as follows:

$$V(M_2 \geq M_1) = hgt\left(M_1 \cap M_2\right) = \mu_{M_2}(d) = \begin{cases} 1, & if \quad m_2 \geq m_1, \\ 0, & if \quad l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise, \end{cases} \tag{11}$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} as shown in Figure 2. To compare M_1 and M_2, both of the values, i.e. $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ need to be considered.

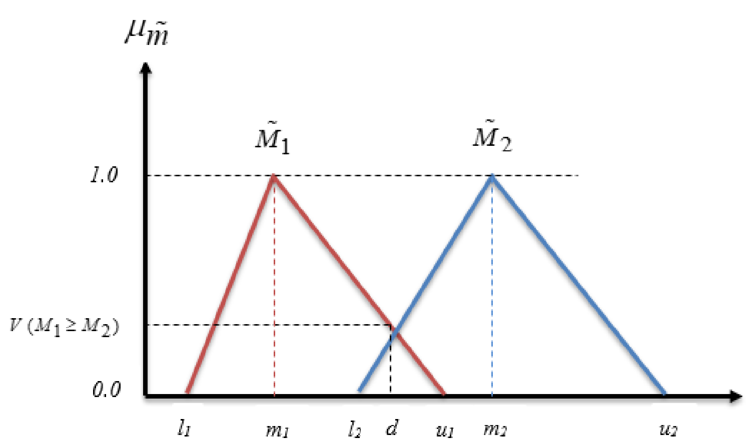

Figure 2. The intersection between M_1 *and* M_2

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

$$\begin{aligned} V(M \geq M_1, M_2, \ldots M_k) &= V\left[\left(M \geq M_1\right) and \left(M \geq M_2\right) and \ldots and \left(M \geq M_k\right)\right] \\ &= \min V\left(M \geq M_i\right), \quad i = 1, 2, \ldots, k. \end{aligned} \tag{12}$$

assume that $d'(A_i) = \min V(S_i \geq S_k)$ for $k = 1, 2, ..., n; k \neq i$. then, the weight vector is given by:

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T, \tag{13}$$

where A_i $(i = 1, 2, \ldots, n)$ are n elements.

$$d(A_i) = \frac{d'(A_i)}{\sum_{i=1}^{n} d'(A_i)} \tag{14}$$

Step 4, The normalized weight vectors elements are:

$$W = \left(d(A_1), d(A_2), \ldots, d(A_n)\right)^T, \tag{15}$$

where W contains crisp numbers. Afterwards, we obtain the final weights of the criteria, W*, considering the interrelationships using super decision software.

In the fourth step of the MARA approach, we can define the robustness-debility matrix denoted by B, consisting of m rows and q columns where each row corresponds to a sub-strategy $S_j, j = 1, \ldots, m$. Each column corresponds to a scenario $Sn_i, i = 1, \ldots, q$. To specify the element *(j, i)* of B, the ordered 6-tuple Sn_i should be compared with the ordered 6-tuples S_j^+ and S_j^-. For each compliance of Sn_i and S_j^+, a positive score being equal to the final weight is assigned, while for each compliance of Sn_i and S_j^-, a negative score being equal to the final weight is considered. The element B_{ji} of matrix B is the sum of the mentioned numbers.

Next, according to the classical Rosenhead's approach [28], two m-tuple vectors R and D are defined to contain robustness and debility of the sub-strategies, respectively. The jth component of R (i.e. R_j) represents the ratio of the number of positive elements of the jth row of B to q (total number of the elements of the jth row), and the jth component of D (i.e. D_j) refers to the ratio of the number of negative elements of the jth row of B to q. Finally, for each main strategy MS_i, the robustness level is defined as the sum of the elements of R corresponding to the related sub-strategies, and the debility level is given by summing the elements of D corresponding to the related sub-strategies (see equation (1)). The best main strategy is determined by comparing the obtained robustness and debility levels.

3. The Real-world Problem

This study uses the same case applied by Sorourkhah et al. [33, 34] to show the substantial effect of this complexity aspect, the criteria interactions. This case is devoted to the automotive industry of Iran. At the first stage, the grand strategy matrix proposed by David [9] was applied to define the strategies and their sequences. Hence, the main strategies were classified into the four groups of offensive (MS_1), competitive (MS_2), defensive (MS_3) and conservative (MS_4). Each of the main strategies consists of some sub-strategies demonstrated based on the equation (1) as follows:

$$MS_1 = S_1 \oplus S_2 \oplus S_3 \oplus S_8 \oplus S_9 \oplus S_{10}, \tag{16}$$

$$MS_2 = S_3 \oplus S_4 \oplus S_5 \oplus S_6, \tag{17}$$

$$MS_3 = S_3 \oplus S_5 \oplus S_7 \oplus S_8, \tag{18}$$

$$MS_4 = S_2 \oplus S_8 \oplus S_9 \oplus S_{10} \oplus S_{11}, \tag{19}$$

Here, the sub-strategies are classified as the vertical integration (S_1), the horizontal integration (S_2), the concentric diversification (S_3), the horizontal diversification (S_4), the conglomerate diversification (S_5), the joint venture (S_6), the retrenchment (S_7), the divestiture (S_8), the market development (S_9), the market penetration (S_{10}) and the product development (S_{11}). In the second step, the scenarios are defined based on probable situations of the PESTEL factors shown in Table 2. Furthermore, based on equation (2), the scenario matrix M can be defined.

Table 2. Factors affecting the problem and their different states

Factors	Indicators	Situation
Political	Joint Comprehensive Plan of Action (JCPOA)	Continuation of JCPOA **(P_1)** Rejection of JCPOA **(P_2)**
Economic	Economic growth	Positive **(Ec_1)** Negative **(Ec_2)**
Social	The potential of market size	Improvement **(So_1)** Stability **(So_2)** Decline **(So_3)**
Technological	Technology development	Maintaining technology over the period under review **(T_1)** Changing the technology to the benefit of the organization **(T_2)** Changing the technology to the detriment of the organization **(T_3)**
Environmental	Community's sensitivity to the environmental degradation	Disregarding **(En_1)** Highly regarding **(En_2)**
Legal	Supporting the domestic monopoly	Continue to support **(L_1)** Ending the support **(L_2)**

$$M = \begin{pmatrix} 1 & 2 & 1 & 1 & 1 & 2 & 2 & 2 & 1 & 2 & 2 & 1 & 2 & 1 & 2 \\ 1 & 1 & 2 & 1 & 2 & 1 & 2 & 2 & 1 & 1 & 1 & 2 & 2 & 2 & 2 \\ 1 & 3 & 2 & 1 & 2 & 2 & 1 & 3 & 3 & 1 & 2 & 3 & 2 & 3 & 3 \\ 1 & 2 & 1 & 3 & 2 & 1 & 1 & 1 & 3 & 2 & 1 & 1 & 2 & 1 & 3 \\ 1 & 2 & 1 & 1 & 2 & 1 & 1 & 2 & 1 & 2 & 1 & 1 & 2 & 1 & 2 \\ 1 & 1 & 1 & 2 & 1 & 2 & 2 & 1 & 2 & 1 & 1 & 2 & 1 & 1 & 2 \end{pmatrix}.$$

In the next step, the strategic condition matrix A indicating favorability or non-favorability conditions of each strategy were determined by the experts as follows:

$$A = \begin{pmatrix} 0 & 0 & 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 1 & 2 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 1 & 0 & 0 & 2 & 1 & 2 & 1 & 1 & 2 & 1 & 2 & 1 & 2 \\ 1 & 3 & 1 & 3 & 0 & 0 & 2 & 3 & 0 & 0 & 2 & 3 & 3 & 1 & 3 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 3 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 3 & 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 3 \\ 0 & 0 & 0 & 0 & 1 & 2 & 1 & 2 & 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 2 & 1 & 2 & 0 & 0 & 0 & 0 & 1 & 2 & 0 & 0 & 0 & 0 & 1 & 2 & 1 & 2 & 0 & 0 \end{pmatrix}.$$

Here, we use the FANP method to obtain the final weights of the criteria. So, we need to form the fuzzy pairwise comparison matrix according to linguistic variables shown in Table 3.

Table 3. Linguistic variables for the FANP and the corresponding TFN [5]

Linguistic terms	Fuzzy number	Inverse fuzzy number
Same preference	(1,1,1)	(1,1,1)
Intermediary	(1,2,3)	(1/3,1/2,1)
A little preferred	(2,3,4)	(1/4,1/3,1/2)
Intermediary	(3,4,5)	(1/5,1/4,1/3)

Equally preferred	(4,5,6)	(1/6,1/5,1/4)
Intermediary	(5,6,7)	(1/7,1/6,1/5)
Preferred a lot	(6,7,8)	(1/8,1/7,1/6)
Intermediary	(7,8,9)	(1/9,1/8,1/7)
Completely preferred	(8,9,10)	(1/10,1/9,1/8)

Table 4. Fuzzy pairwise comparison

	P	***Ec***	***So***	***T***	***En***	***L***
P	(1,1,1)	(1,2,3)	(2,3,4)	(3,4,5)	(4,5,6)	(4,5,6)
Ec	(0.33,0.5,1)	(1,1,1)	(1,2,3)	(2,3,4)	(4,5,6)	(4,5,6)
So	(0.25,0.33,0.5)	(0.33,0.5,1)	(1,1,1)	(1,2,3)	(3,4,5)	(4,5,6)
T	(0.2,0.25,0.33)	(0.25,0.33,0.5)	(0.33,0.5,1)	(1,1,1)	(4,5,6)	(4,5,6)
En	(0.17,0.2,0.25)	(0.17,0.2,0.25)	(0.2,0.25,0.33)	(0.17,0.2,0.25)	(1,1,1)	(1,1,1)
L	(0.17,0.2,0.25)	(0.17,0.2,0.25)	(0.17,0.2,0.25)	(0.17,0.2,0.25)	(1,1,1)	(1,1,1)

As shown in Table 4, the pairwise comparison matrix is available. Now, applying equations 7 ro 15, we have the results given in Table 5.

Table 5. The initial weights of the criteria (*W*)

Factor	***P***	***Ec***	***So***	***T***	***En***	***L***
W	0.35	0.28	0.20	0.17	0	0

Here, the initial weights of two criteria, the environmental and legal, is equal to zero, which means these criteria will not be considered in the following steps. Therefore, according to the criteria interactions shown in Figure 3 and using the super decision software, the final weights of the criteria, shown in Table 6, are available.

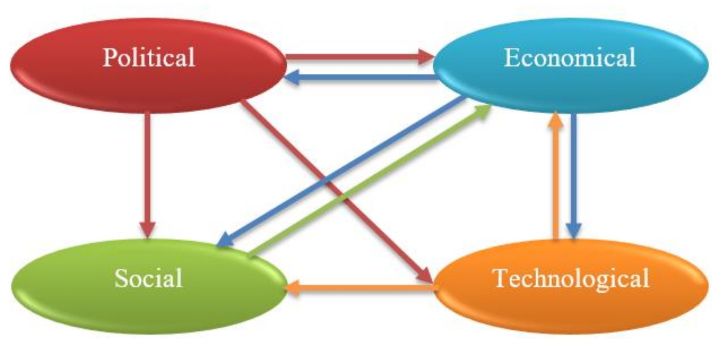

Figure 3. The intersections among criteria

Table 6. The final weights of the criteria (W^*)

Factor	***P***	***Ec***	***So***	***T***	***En***	***L***
W^*	0.1875	0.375	0.25	0.1875	0	0

Now, in the fourth step of the MARA approach, the matrices *M* and *A* are compared to obtain the following matrix *B*, which contains robustness and debility scores of each strategy in different scenarios:

$$B = \begin{pmatrix} 0,63 & -0,06 & -0,38 & 0,81 & -0,56 & 0,38 & -0,13 & -0,63 & 0,31 & 0,44 & 0,38 & -0,63 & -0,56 & -0,63 & -0,44 \\ 0,44 & -0,44 & 0,19 & 0,44 & 0,19 & -0,19 & 0,06 & -0,44 & -0,06 & 0,06 & -0,19 & -0,06 & -0,19 & -0,06 & -0,44 \\ 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 \\ 0,00 & -0,25 & 0,25 & 0,00 & 0,25 & 0,25 & 0,00 & -0,25 & -0,25 & 0,00 & 0,25 & -0,25 & 0,25 & -0,25 & -0,25 \\ -0,38 & -0,19 & 0,38 & -0,56 & 0,56 & -0,38 & 0,38 & 0,38 & -0,56 & -0,19 & -0,38 & 0,38 & 0,56 & 0,38 & 0,19 \\ 0,19 & -0,44 & 0,44 & 0,00 & 0,06 & 0,44 & 0,19 & -0,06 & -0,25 & -0,19 & 0,44 & -0,06 & 0,06 & -0,06 & -0,25 \\ -0,81 & 0,06 & 0,19 & -0,81 & 0,19 & -0,19 & 0,31 & 0,81 & -0,31 & -0,44 & -0,19 & 0,44 & 0,56 & 0,44 & 0,81 \\ -0,81 & 0,06 & 0,19 & -0,81 & 0,19 & -0,19 & 0,31 & 0,81 & -0,31 & -0,44 & -0,19 & 0,44 & 0,56 & 0,44 & 0,81 \\ 0,38 & 0,38 & -0,38 & 0,38 & -0,38 & 0,38 & -0,38 & -0,38 & 0,38 & 0,38 & 0,38 & -0,38 & -0,38 & -0,38 & -0,38 \\ 0,38 & 0,38 & -0,38 & 0,38 & -0,38 & 0,38 & -0,38 & -0,38 & 0,38 & 0,38 & 0,38 & -0,38 & -0,38 & -0,38 & -0,38 \\ 0,38 & 0,56 & -0,38 & 0,19 & -0,19 & 0,38 & -0,38 & -0,38 & 0,19 & 0,56 & 0,38 & -0,38 & -0,19 & -0,38 & -0,56 \end{pmatrix},$$

Consequently, using the data presented in the matrix B, the Rosenhead's classical scheme for calculating robustness and debility of the strategies leads to the vectors R and D as follows:

$$R = [\frac{6}{15} \quad \frac{6}{15} \quad \frac{0}{15} \quad \frac{5}{15} \quad \frac{8}{15} \quad \frac{7}{15} \quad \frac{9}{15} \quad \frac{9}{15} \quad \frac{7}{15} \quad \frac{7}{15} \quad \frac{7}{15}]^T,$$
$$D = [\frac{9}{15} \quad \frac{9}{15} \quad \frac{0}{15} \quad \frac{6}{15} \quad \frac{7}{15} \quad \frac{7}{15} \quad \frac{6}{15} \quad \frac{6}{15} \quad \frac{8}{15} \quad \frac{8}{15} \quad \frac{8}{15}]^T.$$

Finally, according to the relations 16 to 19, the strategies robustness and debility levels are depicted in Table 7 and Figure 4.

Table 7. Robustness and Debility levels of the main strategies

Strategy	Robustness	Debility
Aggressive	35/90	40/90
Competitive	20/60	20/60
Defensive	26/60	19/60
Conservative	36/75	39/75

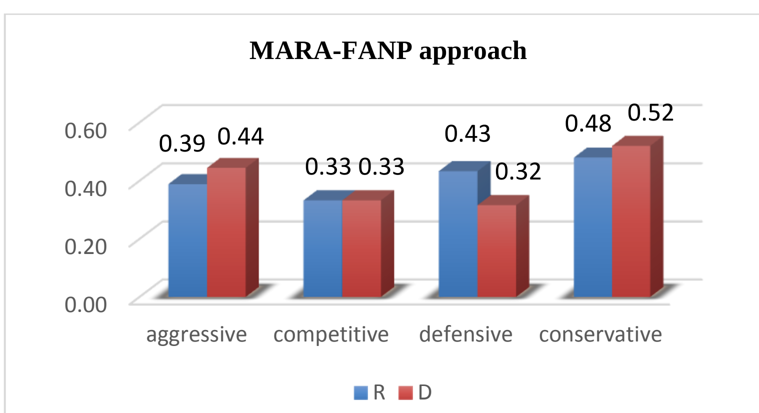

Figure 4. Comparing robustness and debility of the main strategies

Also, the outputs resulted from previous studies we rely on are shown in Figures 5 & 6.

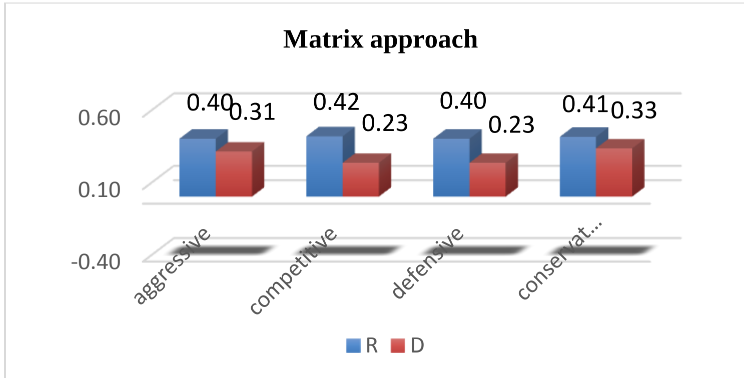

Figure 5. The matrix approach outputs [34]

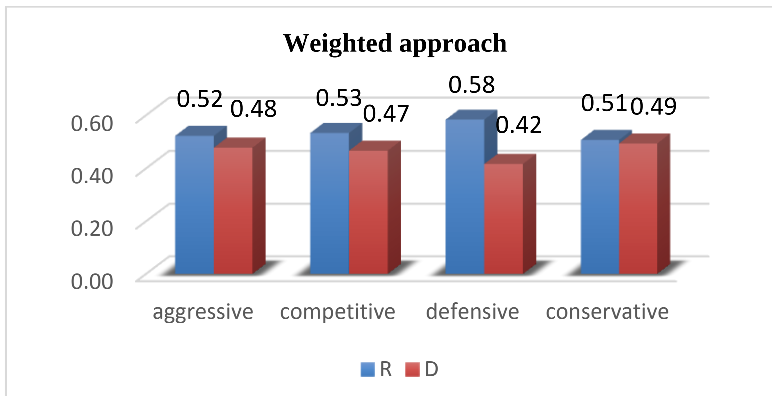

Figure 6. The weighted approach.

4. Conclusions

Today, organizations operate in a very complex and dynamic environment making some difficulties in decision-making, particularly in the strategy selection [35]. Among the most popular approaches introduced in the decision making literature, the classic approach [14, 40]; the scenario planning approach [7, 36]; the MCDM approach [4, 37]; and the robustness approach [10, 18], it is only the last one which can some extent to consider uncertainty and complexity simultaneously. While the fitness of the classic methodologies in conditions with high complexity and uncertainty has been widely questioned [27], the RA approach has many advantages when the uncertainty of assets is at high levels [3]. Recently, developing MARA [33-35] makes the classic RA approach able to cope with another important aspect, complexity: the number of the elements, Scenarios, criteria, etc. But, because the real world criteria are usually interdependent, the previous approaches in this regard cannot be appropriately applied [24]. In this situation, the result obtained using ANP is accurate and scientifically reliable [39].

In this study, a developed version of MARA applying FANP has been introduced for selecting the most reasonable strategy. This approach, on the one hand, deals with the environmental uncertainty by reviewing the performance of the strategies among the alternative futures and the uncertainty related to the preference model of the human decision-maker (uncertain judgements) by using fuzzy set theory, precisely Chang's extent analysis method, and on the other hand, considers desired number of scenarios, criteria and options, and collects experts' judgments in an appropriate time, emphasizing interdependences among criteria. We implemented the approach on a real-world problem used by Sorourkhah et al. [33, 34] to compare the results. In the matrix approach, as shown in Figure 5, it is hard to select the best strategy between competitive and defensive, and in the weighted approach, as shown in Figure 6, this problem has been somehow overcome, but we confront four robust strategies, while such a situation rarely happens in the real world. In comparison, in the proposed approach, as shown in Figure 4, the defensive strategy is the only robust one acceptable, according to the environmental situations as well as possible future of the automotive industry of Iran. Finally, for more studies, using artificial neural networks to define the future scenarios, or replacing FANP with fuzzy DEMATEL-based ANP (FDANP), which has been widely used recently, can be helpful for a decision-maker to achieve a satisfactory result.

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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https://doi: 10.30495/FOMJ.2021.1932066.1029

Received: 31 May 2021 Revised: 5 July 2021 Accepted: 2 July 2021