Ranking of Website Structures Using Fuzzy TOPSIS Method with Type-2 Fuzzy Numbers

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Abstract: - Due to gigantic size of some websites and their complex structures, prioritizing the various structures turns to be a decision making problem incorporating large uncertainty in judgment. Finding a response to such a need, the Fuzzy TOPSIS method, a combination of the TOPSIS method and Fuzzy theory, could heal some of shortcomings of uncertainties in decision making. However there are still lots of occasions in which decision making is faced with lots of uncertainties making the Fuzzy TOPSIS method not adequately responsive. As a sensible response to this drawback, in this paper, we utilize a brand-new extension of TOPSIS and Fuzzy TOPSIS methods, called Interval Valued Fuzzy TOPSIS with ability to cope with type-2 fuzzy environment and data incorporating much more vagueness in decision making.

Key-Words: Website Structure; TOPSIS; Fuzzy Sets Theory; Type-2 Fuzzy Numbers; MCDM; IVF-TOPSIS

1 Introduction

Nowadays websites play a significant role in success of an e-business and giving more intelligence to e-commerce sites is popularly recognized as one of the effective strategies that increases customer satisfaction because they react intelligently and can give a personalized response to each customer [1]. The majority of homes around the world now has computers and uses the Internet so frequently. It is, then, no small wonder that most companies feel that they need at least some level of web presence today. The question facing all companies contemplating web initiatives is how to build a successful website [1-3].

To analyze and capture visitors' opinions about website usability, different methods and metrics are proposed [4, 5]. While in some cases, web designs are measured according to their formatting, composition and different web topic categorization and also some scales focus on customer evaluations and different customer groups [6, 7], many studies use operation research (OR) methods to evaluate website usability [8] and enjoy OR potentials in formulating website link structure as mathematic relations. Also, the graph theory has recently attracted many attentions in website usability evaluation [9].

Developing Information Technology (IT) in recent years, most of state-run organizations in Iran have focused mostly on their websites. In the current environment, the level of quality of web design and web services is a comparison factor between IT departments of different state-run organizations and firms. Chief Information Officers (CIOs) of these organizations care about website of others' so they spend considerable amount of their budget and time to enhance their own website's appearance and structure. In other words, nowadays website architecture and its content play the role of performance measurement criteria of an organization.

Considering another point of view, one of the main responsibilities of Civil Aviation Organization (CAO) is providing the companies and customers with the latest information of the aviation industry, ranging from the most specialized information such as airline and aviation regulations to some general information such as flights' status, scheduling and so on.

Having the hits rate of more than 100-150 person/day, Iranian CAO web site is playing an integral role of a portal for the Iranian aviation industry presenting large number of static and dynamic services to various users and clients. Thus, large number of new web pages are designed and added to/substituted by the previous web pages in the web site structure on a monthly basis aiming to simplify the users' access to the intended information as much as possible. Having such a gigantic size, providing an effective way of navigation for such a link structure is a real woe for the team of web designers these days. During

previous months, from February 2006 to October 2006, the website of Iranian Civil Aviation Organization (CAO) (http://*www.cao.ir*) has been frequently changed to have better face to users. During this period of time, different homepages were developed. The homepage and link structure were dramatically changed again and again and imposed a considerable amount of cost on the department monetarily and time wise. Being faced with various developed structures for CAO website a ranking and evaluation system was needed to rank the various structures and to enable the web designers to choose the best structure for online presentation.
Considering such a problem, taking in to account the existing uncertainty in judging and ranking the various structures developed for CAO website, this paper will introduce a brand new extension of TOPSIS method, an outstanding Multi Criteria Decision Making (MCDM) method, and Fuzzy TOPSIS (F-TOPSIS), a proposed combination of the TOPSIS method and ordinary Fuzzy sets theory aiming at modeling the existing uncertainties in decision making to some extent. Following such intention, the type-2 fuzzy notion, an extension to the fuzzy concept has been utilized. In this regards, next section of this paper states the problem then in the third section the main contribution of our study is presented discussing the IVF-TOPSIS method and finally last section concludes the whole discussion.

2 Problem Statement

In order to evaluate and rank the various CAO website structures, some criteria were selected from literature, based on the job by Zhang and Dran [10]. As CAO is a state-run company the listed criteria (Table 1) have been selected from the various categories have been proposed by Zhang and Dran.
Having used the criteria, three different scenarios for CAO website were evaluated. As the criteria are some how technical and need some technical information for accurate evaluation, we used 10 different web designers who were engaged with CAO website for more than 2 years as the referees to score the criteria about each developed scenario. Each criterion was scored based on a score range of 1-7, 1 presents an ultimate weak performance while 7 shows an ultimate strong performance of the structure under the related criterion. The decision matrix has been presented in Table 2, based on the average score reached for each structure under each criterion.

TABLE 1
Criteria for Evaluating a Governmental Website

Number	*Criteria*	*Proportional weight*
1	Easy to navigate	0.27
2	Clear layout of info.	0.21
3	Up-to-date info.	0.18
4	Search tools	0.17
5	Accuracy of info.	0.17

TABLE 2
Performance of Three Alternative Scenarios for the Structure of CAO Website System

Scs.	*Criterion 1*	*Criterion 2*	*Criterion 3*	*Criterion 4*	*Criterion 5*
1	2	6	5	3	7
2	4	3	4	5	6
3	6	4	2	4	6

3 Introducing Type-2 Fuzzy TOPSIS Method

Due to the huge vagueness in scoring three scenarios based on the five criteria, the potential variation in each alternative score was brought in to attention. Based on the designers' comments on their scores the following variations (Table 3) are possible in the scores given to three scenarios in Table 2. Also Table 4 presents the ordinary triangular fuzzy numbers obtained by applying the variations, as indicated in Table 3, to the scores in Table 2. Type-2 fuzzy, which is also called Interval Valued Fuzzy (IVF), concept has been proposed by Turksen [11] and also Gorzalczany [12], which contributes to the situations when it is not possible for a membership function of the type $\mu : X \rightarrow [0,1]$ to assign an exact value from the interval [0,1] to each element $x \in X$ without losing some information. In these situations the membership degree is defined as a continuum of values ranging over the interval of [0,1] rather than an exact value selected from the interval of [0,1]. Below is the mathematical description of interval valued fuzzy concept [12]:

$$A = \left\{ x, [\mu_A^L(x), \mu_A^U(x)] \right\}, \quad x \in X$$
$$\mu_A^L, \mu_A^U : X \rightarrow [0,1]; \quad \forall x \in X,\ \mu_A^L(x) \leq \mu_A^U(x) \qquad (1)$$

Let: $\bar{\mu}_A(x) = \left[\mu_A^L(x), \mu_A^U(x)\right], x \in X$ where x represents a member of an interval-valued fuzzy set of X, and

TABLE 3
The Variations in Scoring the Various Scenarios of CAO Website based on each Criterion

Criteria	*Scenarios*	*Variations*
Criterion 1	Scenario 1	-10% to $+10\%$
	Scenario 2	-5% to $+10\%$
	Scenario 3	-10% to $+5\%$
Criterion 2	Scenario 1	-5% to $+10\%$
	Scenario 2	-5% to $+5\%$
	Scenario 3	-20% to $+10\%$
Criterion 3	Scenario 1	-5% to $+10\%$
	Scenario 2	-15% to $+5\%$
	Scenario 3	-5% to $+10\%$
Criterion 4	Scenario 1	-15% to $+10\%$
	Scenario 2	-15% to $+5\%$
	Scenario 3	-5% to $+5\%$
Criterion 5	Scenario 1	-5% to $+10\%$
	Scenario 2	-15% to $+10\%$
	Scenario 3	-5% to $+5\%$

$[\mu_A^L(x), \mu_A^U(x)]$ stands for an interval representing the membership degree of x in X. In this interval μ_A^L stands for the lower (smaller in amount) and μ_A^U stands for the upper (bigger in amount) boundary of the interval [12].

In precedence, Guijun and Xiaoping [13] defined the concept of interval valued fuzzy number along with the operations using these numbers. We have used this definition throughout our research for doing the calculations. The definitions of the interval valued fuzzy numbers and the operations using these numbers have been mentioned as follows [13, 14]:

TABLE 4
The CAO Website Alternatives' Scores after Applying the Potential Variations Using Triangular Fuzzy Numbers

Criteria	*Criterion 1*			*Criterion 2*		
Fuzzy No.	*a*	*m*	*b*	*a*	*m*	*b*
Scen. 1	0.077	0.086	0.094	0.181	0.191	0.210
Scen. 2	0.163	0.171	0.189	0.091	0.095	0.100
Scen. 3	0.231	0.257	0.270	0.102	0.127	0.140
Criteria	*Criterion 3*			*Criterion 4*		
Scen. 1	0.155	0.164	0.180	0.083	0.097	0.107
Scen. 2	0.111	0.131	0.137	0.138	0.162	0.170
Scen. 3	0.062	0.065	0.072	0.123	0.130	0.136
Criteria	*Criterion 5*					
Scen. 1	0.147	0.155	0.170			
Scen. 2	0.113	0.132	0.146			
Scen. 3	0.126	0.132	0.139			

Definition 1: Let R be an ordinary non-empty set and $[I]$ be a subset of I = $[0,1]$ Then the mapping $A: R \to [I]$ is called an interval-valued fuzzy set on R. All interval-valued fuzzy sets on R are denoted by *IF(R)*.

Definition 2: If $A \in IF(R)$, let $A = [A^-(x), A^+(x)]$ where $x \in R$. Then two ordinary fuzzy sets $A^-: R \to I$ and $A^+: R \to I$ are called lower fuzzy set and upper fuzzy set about A, respectively.

Definition 3: Consider $A \in IF(R)$, i.e., $A: R \to [I]$. Assume the following conditions are satisfied:

1) A is normal, i.e., there exists $x_0 \in R$ such that $A(x_0) = 1$.
2) When:
$$A_{[\lambda_1, \lambda_2]} = \{ x \in R,\ A^-(x) \le \lambda_1,\ A^+(x) \le \lambda_2 \},$$
for arbitrary $[\lambda_1, \lambda_2] \in [I] - \{ \bar{0} \}$, $A_{[\lambda_1, \lambda_2]}$ is closed bounded interval.

Then we call A an interval-valued fuzzy number on real line R. $IF^*(R)$ denotes the set of all interval-valued fuzzy numbers on R.

Definition 4: Let $A, B \in IF^*(R)$ and $\circ \in \{ +, -, \times, \div \}$ then:

$$(A \circ B)(z) = [(A^- \circ B^-)(z), (A^+ \circ B^+)(z)] \qquad (2)$$

Based on the given definitions above, the performances of alternatives along with their calculations can be presented using interval valued fuzzy numbers. We can express an interval valued fuzzy number as $A = [(a, a'), m, (b', b)]$ in which $A^- = (a', m, b')$ and $A^+ = (a, m, b)$ are triangular fuzzy umbers as the lower and upper limits around

A, respectively.

Considering the fact that, in some cases, determining the degree of membership precisely is rather impossible or difficult, the degree of membership can be expressed as an interval of real numbers instead. Based on this ground, in this paper the alternatives' performance values are considered as type-2 fuzzy numbers.

Suppose $A_1, A_2, \ldots, A_n$ are m possible alternatives among which decision makers have to select, and $C_1, C_2, \ldots, C_m$ are the criteria with which alternative performance are measured, r_{ij} is the performance value of the alternative A_i with respect to criterion C_j and as shown in Fig. 1 is a type-2 triangular fuzzy number.

$$r_{ij} = [(a'_{ij}, a_{ij}), m_{ij}, (b_{ij}, b'_{ij})] \quad (3)$$

Now we can propose an algorithmic approach to develop the TOPSIS for interval-valued fuzzy data (IVF-TOPSIS) as follows [15]:

1. Consider $x_{ij} = \left[\left(a'_{ij}, a_{ij}\right), m_{ij}, \left(b_{ij}, b'_{ij}\right)\right]$, the normalized performance value, can be calculated as:

$$\tilde{r}_{ij} = [(\frac{a'_{ij}}{b'^*_j}, \frac{a_{ij}}{b'^*_j}), \frac{m_{ij}}{b'^*_j}, (\frac{b_{ij}}{b'^*_j}, \frac{b'_{ij}}{b'^*_j})], \quad j \in B \quad (4)$$

$$b'^*_j = \max_i b'_{ij}, \quad \text{if} \quad j \in B$$

2. Considering the normalized decision matrix, the positive and negative ideal solutions are defined as $A^- = [0, 0, 0, 0, 0]$ and $A^+ = [1, 1, 1, 1, 1]$, respectively.

3. The separation (distance) of each alternative from the positive ideal solution can be currently calculated as $\left[D^+_{i1}, D^+_{i2}\right]$, where:

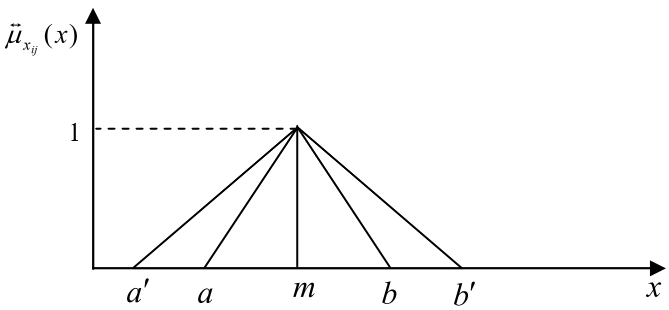

Fig. 1. Type-2 triangular fuzzy number [15]

$$D^+_{i1} = \sum_{j=1}^{m} \sqrt{\frac{1}{3}\left[\left(a_{ij}-1\right)^2 + \left(m_{ij}-1\right)^2 + \left(b_{ij}-1\right)^2\right]}$$

$$D^+_{i2} = \sum_{j=1}^{m} \sqrt{\frac{1}{3}\left[\left(a'_{ij}-1\right)^2 + \left(m_{ij}-1\right)^2 + \left(b'_{ij}-1\right)^2\right]} \quad (5)$$

Similarly, the separation from the negative ideal solution is given as $\left[D^-_{i2}, D^-_{i1}\right]$, where:

$$D^-_{i1} = \sum_{j=1}^{m} \sqrt{\frac{1}{3}\left[\left(a_{ij}-0\right)^2 + \left(m_{ij}-0\right)^2 + \left(b_{ij}-0\right)^2\right]}$$

$$D^-_{i2} = \sum_{j=1}^{m} \sqrt{\frac{1}{3}\left[\left(a'_{ij}-0\right)^2 + \left(m_{ij}-0\right)^2 + \left(b'_{ij}-0\right)^2\right]} \quad (6)$$

4. The relative closeness of the alternative A_i is defined as:

$$RC_1 = \frac{D^-_{i2}}{D^+_{i1} + D^-_{i2}} \quad , \quad RC_2 = \frac{D^-_{i1}}{D^+_{i2} + D^-_{i1}} \quad (7)$$

Then the final values of RC^*_i can be determined by:

$$RC = \frac{RC_1 + RC_2}{2} \quad (8)$$

In the subsequent section, we will do the ranking utilizing ordinary TOPSIS and type-2 fuzzy TOPSIS methods, which are discussed in comparison in final section of this paper.

4 Ranking the Scenarios

4-1 Utilizing Ordinary TOPSIS

Utilizing the ordinary TOPSIS method, the ranking of three scenarios, as indicated in Table 5, was reached based on the crisp data presented in Table 2. As has been presented in Table 5, we have used the conventional method of ordinary TOPSIS for ranking the three various scenarios of CAO decision making problem. Having done so, we reach the ranking of $3 \rightarrow 2 \rightarrow 1$ stating the domination of the third scenario over the second one and the second one over the first scenario. Doing so, we have considered all the input data as some crisp values, so no uncertainty has taken into account in obtained ranking. During the next part of this section we utilize the brand-new method of type-2 fuzzy TOPSIS for calculating the ranking. The comparison and contrast of obtained results of these two various methods will be discussed during last section of this paper.

4-2 Utilizing Type-2 Fuzzy TOPSIS

According to the large degree of uncertainty in

TABLE 5
The result of applying ordinary TOPSIS method for evaluation and ranking three CAO website scenarios

Scenarios	D_i^+	D_i^-	RC	Final Ranking
1	0.151	0.062	0.292	$3 \rightarrow 2 \rightarrow 1$
2	0.114	0.088	0.436	
3	0.100	0.078	0.438	

evaluating the three different CAO website scenarios using five criteria, we asked the web designers to give us the potential variation in the number they had already provided us with, Table 3, as the potential variation of scenarios performances' scores under each criterion (Table 6). These variations can describe the underlying uncertainties in scoring the three different scenarios more accurately leading to a better and more accurate ranking of three scenarios. The resulting comments are as follow:

Table 7, shows the mentioned variations in terms of triangular interval valued fuzzy numbers based on each criterion, having weighted and normalized using equation 4.

Calculating the indices as presented and described in equations 5-8, the results are obtained as illustrated in Table 8.

5 Conclusion

In this paper we have utilized the type-2 fuzzy TOPSIS method tackling the problems with the criteria values as type-2 fuzzy numbers. The results show that the more uncertainty is modeled, the more accurate final result is obtained. Making decision over a case with lots of uncertainty and vagueness requires going in to more details considering the underlying fuzziness more, where a type-2 fuzzy based MCDM method can be much more effective in contrast to ordinary MCDM methods. Considering TOPSIS as the selected MCDM method and extending along with utilizing type-2 fuzzy TOPSIS, the results show that the underlying uncertainty in scoring the third alternative and modeling the web designers' intention to increase the third alternative's scores cause the third alternative to be ranked prior to the first one. However such details with this level of accuracy about the decision maker utility function in making his/her decisions could hardly be reached with ordinary TOPSIS method utilization.

Studying the designers' comments about the resulted rankings, all of them were much more satisfied with the resulted ranking obtained based on type-2 fuzzy TOPSIS method, saying that it can describe their intentions much more precisely in comparison with ordinary TOPSIS method. As all three structures were almost desirable for web designers, this could incorporate high degree of uncertainty in their judgments about the priority of the different structures. However as the type-2 fuzzy based TOPSIS can further describe the fuzziness in their judgments, it can show their intentions more precisely through the obtained ranking.

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TABLE 6
The variations in scoring the various scenarios of CAO website based on each Criterion

Criteria	*Scenarios*	*Lower variation in scenarios*	*Upper variation in scenarios*
Criterion 1	Scenario 1	-50% to $+50\%$	-90% to $+40\%$
	Scenario 2	-60% to $+10\%$	-50% to $+100\%$
	Scenario 3	-90% to $+50\%$	-80% to $+50\%$
Criterion 2	Scenario 1	-20% to $+50\%$	-60% to $+10\%$
	Scenario 2	-20% to $+10\%$	-20% to $+100\%$
	Scenario 3	-90% to $+30\%$	-50% to $+10\%$
Criterion 3	Scenario 1	-20% to $+50\%$	-60% to $+30\%$
	Scenario 2	-10% to $+20\%$	-30% to $+100\%$
	Scenario 3	-90% to $+30\%$	-50% to $+60\%$
Criterion 4	Scenario 1	-50% to $+10\%$	-60% to $+30\%$
	Scenario 2	-10% to $+10\%$	-30% to $+100\%$
	Scenario 3	-50% to $+30\%$	-50% to $+30\%$
Criterion 5	Scenario 1	-50% to $+10\%$	-60% to $+10\%$
	Scenario 2	-10% to $+20\%$	-30% to $+80\%$
	Scenario 3	-50% to $+10\%$	-50% to $+20\%$

TABLE 7

CAO Website Alternatives' Weighted Normalized Scores in terms of Triangular Type-2 Fuzzy Numbers

Scenarios	*Criterion 1*					*Criterion 2*				
	a'	a	m	b	b'	a'	a	m	b	b'
1	0.071	0.080	0.084	0.085	0.095	0.175	0.182	0.189	0.197	0.210
2	0.158	0.164	0.167	0.176	0.201	0.089	0.091	0.095	0.098	0.104
3	0.213	0.249	0.251	0.254	0.270	0.093	0.124	0.126	0.132	0.140
Scenarios	*Criterion 3*					*Criterion 4*				
	a'	a	m	b	b'	a'	a	m	b	b'
1	0.144	0.149	0.156	0.162	0.180	0.077	0.086	0.093	0.096	0.105
2	0.102	0.108	0.125	0.129	0.137	0.129	0.134	0.155	0.160	0.170
3	0.058	0.062	0.062	0.065	0.072	0.116	0.121	0.124	0.127	0.132
Scenarios	*Criterion 5*									
	a'	a	m	b	b'					
1	0.145	0.149	0.153	0.161	0.170					
2	0.108	0.114	0.131	0.140	0.155					
3	0.124	0.128	0.131	0.135	0.140					

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TABLE 8

The Weighted Normalized Performance of Three Alternative Scenarios for The Structure of CAO Website System

	D_{iL}^{+}	D_{iU}^{+}	D_{iL}^{-}	D_{iU}^{-}	RC_1	RC_2	RC	*Ranking*
Scenario. 1	4.3108	4.3243	0.6741	0.6852	0.1349	0.1372	0.1360	$3 \rightarrow 1 \rightarrow 2$
Scenario. 2	4.3225	4.3383	0.6633	0.6796	0.1326	0.1359	0.1342	
Scenario. 3	4.3031	4.3033	0.6876	0.6968	0.1394	0.1378	0.1386	