

An Application of Type-2 Fuzzy Notions in Website Structures Selection: Utilizing Extended TOPSIS Method

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Abstract: Giving more effectiveness to e-commerce sites increases customer satisfaction as visitors can navigate the website easier and find their targets in less time and cost. With the development of web content, the structure of a website becomes more complex and critical to both web designers and users in a way that has made the prioritizing of various options of website structure a pivotal decision making problem incorporating large uncertainty in judgment. Finding a response to such a need, TOPSIS, a conventional MADM technique, had been a mere remedy for years, solving the problems with a more or less adequate accuracy. In an aspiring step toward an improvement in this method, Fuzzy TOPSIS method, a combination of ordinary TOPSIS method and Fuzzy theory, could heal some of shortcomings of uncertainties and ordinary TOPSIS in decision making. However there are still lots of occasions in which decision making is faced with lots of shadowiness making the Fuzzy TOPSIS method not sufficiently receptive. As a sensible response to this drawback, in this paper, we utilize a brand-new extension to TOPSIS and Fuzzy TOPSIS methods, based on type-2 fuzzy notions with ability to cope with type-2 fuzzy environment and data incorporating much more fuzziness in decision making. We apply this method to a vague case of the real world and discuss its results against the other previously-developed TOPSIS methods.

Key-Words: Decision Making; Website Structure; TOPSIS; Type-2 Fuzzy Sets; Interval Valued Fuzzy Sets; MADM; Fuzzy TOPSIS; IVF-TOPSIS

1 Introduction

Prevailing of World Wide Web and developing of web content, necessity of more effective websites has become a major concern in the e-business industry. The majorities of homes around the world now have computers and use 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].

Analyzing the website usability, various metrics, such as: visitor-type metrics, web content metrics, stay duration metrics, exposure metrics, reach metrics, visits frequency metrics, interactivity metrics and etc [4], and methods, such as: activity theory based method [5], cognitive walkthrough for the web (CWW) method [6], Internet usage style based method [7], hyperlink based inference method [8] and etc, are introduced and applied in the literature. 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 [9, 10], many studies use operation research (OR) methods to evaluate website usability [11] 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 [12].

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 Iranian 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.

As a conventional MCDM technique, TOPSIS has been applied for years solving the decision making problems by providing a ranking of the existing alternatives based on some pre-determined and evaluated criteria. However, TOPSIS invariably suffers from lack of enough ability to cope with uncertain situations and problems. Considering such a drawback, 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 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 goes to the research methodology then in the third section the main results of our study are discussed in brief including the comparison among TOPSIS, F-TOPSIS and IVF-TOPSIS methods and finally last section concludes the whole discussions.

2 Problem Definition

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 [13]. 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 [10]

<i>Number</i>	<i>Governmental Criteria</i>	<i>Proportional weight</i>
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

<i>Scs.</i>	<i>Criterion 1</i>	<i>Criterion 2</i>	<i>Criterion 3</i>	<i>Criterion 4</i>	<i>Criterion 5</i>
1	2	6	5	3	7
2	4	3	4	5	6
3	6	4	2	4	6

3 TOPSIS Approach

3.1 Utilizing Ordinary TOPSIS for Ranking the Scenarios

Yoon and Hwang [14], introduced the TOPSIS method based on the idea that the best alternative should have the shortest distance from an ideal solution. They assumed that if each criterion increases or decreases monotonously, then it is easy to define an ideal solution. Such a solution comprises all the best achievable values of criteria, while the worst solution is composed of all the worst criteria values achievable. In brief TOPSIS solution method consists of the following steps:

- Normalize the decision matrix
- Determining the ideal and negative ideal solutions
- Measuring the distance from positive and negative ideal solutions
- Calculating the relative closeness to the ideal solution
- Ranking the alternatives

Utilizing ordinary TOPSIS method, the ranking of three scenarios, as indicated in Tables 3 and 4, was reached based on the crisp data presented in Table 2.

TABLE 3

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

Criteria	Cri.1	Cri.2	Cri.3	Cri.4	Cri.5
Weights	0.27	0.21	0.18	0.17	0.17
Scenario. 1	0.07	0.16	0.13	0.07	0.11
Scenario. 2	0.14	0.08	0.11	0.12	0.09
Scenario 3	0.22	0.11	0.05	0.10	0.09

TABLE 4

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 → 2 → 1
2	0.114	0.088	0.436	
3	0.100	0.078	0.438	

In table 4, D_i^+ and D_i^- are two Euclidean distances for each alternative from positive and negative ideal solutions respectively. RC is the general relative closeness to the ideal solution as the basis of the ranking in ordinary TOPSIS.

3.2 Utilizing Fuzzy TOPSIS for Ranking the Scenarios

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 are possible in the scores given to three scenarios in table 2, as indicated in table 5.

Having reached the potential variations in the scores given by web designers, we used fuzzy TOSIS as has been proposed by [15-18] for ranking the scenarios based up on. Doing so, the following equations, as proposed by [16-18], were used for normalizing the triangular fuzzy numbers:

$$\tilde{r}_{ij} = (\frac{a_{ij}}{b_j^*}, \frac{m_{ij}}{b_j^*}, \frac{b_{ij}}{b_j^*}), \quad j \in B$$

$$b_j^* = \max_i b_{ij}, \quad \text{if } j \in B \quad (1)$$

Table 6 shows the alternatives' scores after applying the potential variations using triangular fuzzy numbers and relative criteria weights.

Reaching a sensible index for ranking the various scenarios, as similarly is the case in ordinary TOPSIS method, we assume the positive and negative ideal solutions as; $A^- = [0, 0, 0]$ and $A^+ = [1, 1, 1]$. The indices of D_i^+ , D_i^- and RC_i are calculated as follows:

$$D_i^+ = \sum_{j=1}^m \sqrt{\frac{1}{3} [(a_i - 1)^2 + (m_i - 1)^2 + (b_i - 1)^2]}$$

$$D_i^- = \sum_{j=1}^m \sqrt{\frac{1}{3} [(a_i - 0)^2 + (m_i - 0)^2 + (b_i - 0)^2]} \quad (2)$$

$$RC_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

Table 6 also represents the final ranking of the three scenarios using the scores presented in Table 5 and indices described above.

3.3 Introducing Type-2 Fuzzy TOPSIS Method

Type-2 fuzzy, which is also called Interval Valued Fuzzy (IVF), concept has been proposed by Turksen [19] and also Gorzalczany [20], 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 [19, 20]. 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 type-2 fuzzy concept [20]:

$$A = \{x, [\mu_A^L(x), \mu_A^U(x)]\}, \quad x \in X$$

$$\mu_A^L, \mu_A^U : X \rightarrow [0, 1]; \quad \forall x \in X, \mu_A^L(x) \leq \mu_A^U(x) \quad (3)$$

Let $\bar{\mu}_A(x) = [\mu_A^L(x), \mu_A^U(x)]$, $x \in X$ where x represents a member of a type-2 fuzzy set of X , and $[\mu_A^L(x), \mu_A^U(x)]$ 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 [20].

In precedence, Guijun and Xiaoping [21] defined the concept of type-2 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 type-2 fuzzy numbers and the operations using these numbers have been mentioned as follows [21, 22]:

Definition 1: Let R be an ordinary non-empty set and $[I]$ be a subset of $I = [0, 1]$. Then the mapping $A : R \rightarrow [I]$ is called a type-2 fuzzy set on R . All type-2 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 $A^- : R \rightarrow I$ and $A^+ : R \rightarrow I$ are called lower fuzzy set and upper fuzzy set about A , respectively.

Definition 3: Consider $A \in IF(R)$, i.e., $A : R \rightarrow [I]$. 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

TABLE 6

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			

$A_{[\lambda_1, \lambda_2]} = \{x \in R, A^-(x) \leq \lambda_1, A^+(x) \leq \lambda_2\}$, for arbitrary $[\lambda_1, \lambda_2] \in [I] - \{\bar{0}\}$, $A_{[\lambda_1, \lambda_2]}$ is closed bounded interval.

Then we call A a type-2 fuzzy number on real line R . $IF^*(R)$ denote the set of all type-2 fuzzy numbers on R .

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

$$(A * B)(z) = [(A^- * B^-)(z), (A^+ * B^+)(z)] \quad (4)$$

Based on the given definitions above, the performances of alternatives along with their

TABLE 5

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%

calculations can be presented using type-2 fuzzy numbers. Fig. 1 illustrates an example of a type-2 fuzzy number.

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, \dots, A_n are m possible alternatives among which decision makers have to select, and C_1, C_2, \dots, 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 triangular type-2

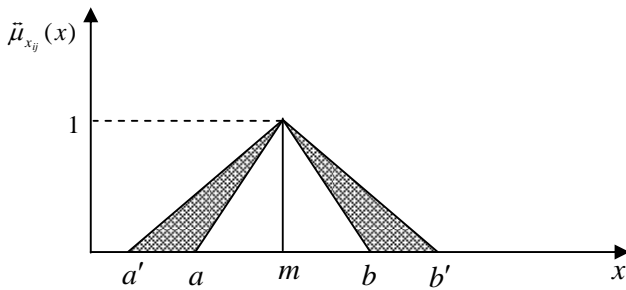


Fig. 1. Triangular type-2 fuzzy number [18]

fuzzy numbers.

$$r_{ij} = [(a'_{ij}, a_{ij}), m_{ij}, (b_{ij}, b'_{ij})] \quad (5)$$

Now the proposed algorithmic approach to develop the TOPSIS for type-2 fuzzy data is as follows [23]:

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

$$\tilde{r}_{ij} = [(\frac{a'_{ij}}{b_j^*}, \frac{a_{ij}}{b_j^*}), \frac{m_{ij}}{b_j^*}, (\frac{b_{ij}}{b_j^*}, \frac{b'_{ij}}{b_j^*})], \quad j \in B \quad (6)$$

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

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

3. Calculating the Euclidean distance:

The separation (Distance) of each alternative from the positive ideal solution can be currently calculated as $[D_{i1}^+, D_{i2}^+]$, where:

$$D_{i1}^+ = \sum_{j=1}^m \sqrt{\frac{1}{3} [(a_{ij} - 1)^2 + (m_{ij} - 1)^2 + (b_{ij} - 1)^2]} \quad (7)$$

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

Similarly, the separation from the negative ideal solution is given as $[D_{i2}^-, D_{i1}^-]$, where:

$$D_{i1}^- = \sum_{j=1}^m \sqrt{\frac{1}{3} [(a_{ij} - 0)^2 + (m_{ij} - 0)^2 + (b_{ij} - 0)^2]} \quad (8)$$

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

4. Calculating the relative closeness:

The relative closeness of the alternative A_i is defined as:

$$RC_1 = \frac{D_{i2}^-}{D_{i1}^+ + D_{i2}^-}, \quad RC_2 = \frac{D_{i1}^-}{D_{i2}^+ + D_{i1}^-} \quad (9)$$

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

$$RC = \frac{RC_1 + RC_2}{2} \quad (10)$$

3.4 Ranking the Scenarios Utilizing Type-2 Fuzzy TOPSIS

According to the large degree of uncertainty in 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 provided us with as the potential variation of scenarios performances' scores under each criterion. 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 indicated in table 7. Table 8, shows the mentioned variations in terms of triangular type-2 fuzzy numbers based on each criterion, having weighted and normalized using equation 5.

Calculating the indices as presented and described in equations 6-9, the results as illustrated in Table 9, are obtained.

4 Conclusion

It is argued that if a fuzzy MCDM problem is defuzzified into a crisp one at the very beginning, then the advantage of collecting fuzzy data becomes unapparent. Based on this fact, in this paper we have developed 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, having applied F-TOPSIS for ranking the alternatives, the degree this method can contribute to the underlying fuzziness in decision making is some how limited.

Facing with very uncertain cases requiring going in to more details considering the underlying fuzziness, the IVF-TOPSIS can be utilized. According to the results, modeling the uncertainty even more in scoring the alternatives has resulted to a more accurate ranking. Applying the IVF-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 not be reached by two preceding methods.

Comparing the various rankings by web designers, most of them were more satisfied with the last one saying that the third ranking can describe their intentions more accurately. As all three structures were almost desirable for web designers, this could make a high degree of uncertainty in their judgments about the priority of the different structures. However as the IVF-TOPSIS can further describe the fuzziness in their judgments, it can

show their intentions more precisely through the obtained ranking. And that's the main reason why most of the designers feel more satisfied with the third ranking.

In a coda to what we argued above, considering three method-evaluation criteria of: the degree of sensitivity the method has to the alternatives' performances, the degree of uncertainty which can be potentially modeled by the method along with the degree of simplicity of the method, we can conclude the comparison and contrast of these three TOPSIS-based methods as table 10, utilizing relative three-point likert of low, medium and high for scoring them.

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TABLE 7

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 8
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					

TABLE 9
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 → 1 → 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	

TABLE 10
The Methods Comparison and Contrast Concluding Results

	Degree of Sensitivity	Ability in Uncertainty Modeling	Simplicity
Ordinary TOPSIS	LOW	LOW	HIGH
Fuzzy TOPSIS	MEDIUM	MEDIUM	MEDIUM
Type 2 Fuzzy TOPSIS	HIGH	HIGH	LOW

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