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A MODEL FOR EVALUATION E-COMMERCE WEB SITES BASED ON FUZZY COMPROMISE PROGRAMMING

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Abstract. In a competitive environment, e-commerce companies should give more importance to their web sites. Therefore, this paper proposes an easy-to-use framework for evaluating the performance of e-commerce Web sites, based on fuzzy compromise programming. The proposed framework is also used for evaluating web sites of some e-Commerce companies in Serbia.

Keywords: Decision-making, E-Commerce, Website analysis, Fuzzy Compromise programming.

Jel classification: D81; C61; C44.

1. Introduction

The increasing use of the Internet has effects in a way that consumers use to obtain services and products. Therefore, e-Commerce, as a new approach for buying and selling products and services via Internet, has become an important tool for many companies around the world, which has a significant influence on the traditional way of performing trade.

According to Porter (1980, 2001) and Porter and Millar (1985), a companies should develop their business strategies in order to obtain competitive advantages, i.e. increase profit, over their competitors. They does this by responding to five primary forces: i) the threat of new entrants, ii) rivalry among existing firms within an industry, iii) the threat of substitute products/services, iv) the bargaining power of suppliers, and v) the bargaining power of buyers.

Compared to the traditional method of selling products and services, e-Commerce can have a much stronger influence on Porter's five forces, especially to rivalry among existing firms within an industry and the bargaining power of buyers. Therefore, many companies have started or intend to start, their e-Commerce, as a complement to the existing method of selling products and services or as a new method of selling.

The use of e-Commerce in different countries varies, from a high presence to the initial attempts. The Serbia can be placed into the group of countries where the use of e-Commerce is still in the initial stage. There are numerous reasons why this is so. Fortunately, a significant number of the company is aware of the advantages which e-Commerce provides, and they make significant activities to increase the share of e-Commerce in the whole sale.

In e-Commerce web site is very important to the success of the business. Therefore, in many journals, numerous of papers are devoted to web sites of companies that use e-Commerce. A numerous authors recognized different criteria, and also different number of criteria, which have affect the quality of e-Commerce sites, and thus to customers satisfaction. These criteria do not have equal importance to customers. Therefore, in this paper we consider e-Commerce web site evaluation as a fuzzy multiple criteria decision making (MCDM) problem.

The aim of this paper is to form an easy to use but also effective MCDM model, which will provides opportunity to decision makers in e-commerce to perform comparisons of their web sites with web sites of their competitors, and based on these comparisons clearer consider the position of their firms in a competitive environment and also make their decisions more accurately. The aim of this paper is to form an easy to use but also effective MCDM model, which will provides opportunity to decision makers in e-commerce to perform comparisons of their web sites with web sites of their competitors, and based on these comparisons clearer consider the position of their firms in a competitive environment and also make their decisions more accurately. Therefore, there is a chosen one set with a small number of evaluation criteria, but sufficient for reliable determination of the quality of web sites, and a relatively simple but effective MCDM method, called the Compromise programming. Due to the complexity of considered problem and manifestations of uncertainty, this paper proposes the application of fuzzy Compromise programming.

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Because of all above mentioned reasons, the rest of this paper is organized as follow. In section 2, a brief review of relevant literature is presented. Then, in section 3, some basic elements of MCDM are considered, and in subsection 3.1 the Compromise programming method is considered. In subsection 3.2. a fuzzy extension of Compromise programming method is given, and in section 4, a framework for e-Commerce web sites evaluation using fuzzy Compromise programming is presented. After that, In section 5, a numerical example is considered with the aim to explain in details the proposed framework. Finally, section 6 presents conclusions.

2. Literature review

There are a large number of papers in the literature devoted to development and evaluation of web sites, but only part of them are dedicated to e-Commerce web sites. Boyd Collins developed the first formal approach to the evaluation of web sites in late 1995. His model, intended for librarians, has been based on six criteria, developed by combining evaluation criteria for printed media, and considering what was relevant for web sites Merwe and Bekker (2003). These criteria are: Contents, Authority, Organizations, Searchability, Graphic design and Innovation use.

Based on customer baying process Berthon *et al*. (1996) and Merwe and Bekker (2013) identified five groups of criteria, namely: Interface, Navigation, Content, Reliability and Technical. These groups of criteria also contain their sub-criteria.

Albuquerque and Belchior (2002) have identified a number of criteria (quality factors), which can be used to evaluate the quality of e-Commerce web site. These criteria are organized in several hierarchical levels, where at the top of proposed hierarchical structure the following criteria are placed: Usability, Conceptual reliability and Representation reliability.

Similar to Merwe and Bekker (2013) and Hung and McQueen (2004) started from a process of purchasing products and services using e-Commerce. Based on that process they have introduced satisfaction model for e-Commerce buyers and also identified three failure points in the proposed satisfaction model. They also identified four key criteria: Ease-of-identification, Ease-of-use, Usefulness, and Interactivity.

Besides the previously mentioned researches, studies designed to identify the criteria that are significant for the evaluation of e-Commerce web site are still actual. For example Dumitrache (2010) gives an overview of criteria used for evaluation of e-Commerce sites in Romania, during the period 2006 and 2009. It also states Navigability, Response Time, Personalization, Tele-presence and Security as very important criteria.

Davidaviciene and Tolvaisas (2011) identify the list of criterions for quality evaluation of e-Commerce web site. They also provide a comprehensive overview of the criteria that are recently proposed by different authors. In accordance with (Davidaviciene, Tolvaisas 2011) criteria: Easy to use, Navigation, Security assurance, Help (real time) and Design have been discussed by numerous authors, such as (Loiacono *et al*. 2007; Parasuraman *et al*. 2007; Cao *et al*. 2005; Calero *et al*. 2005).

Aydinand and Kahraman (2012) proposed a fuzzy multiple criteria decision making model for evaluation of e-Commerce web sites. Their model contains five criteria and twenty sub-criteria, where the key criteria are: Ease of use, Products, Security, Customer relation ship and Fulfilment.

3. Multiple Criteria Decision Making

The process of selecting, or more precisely, determining the best option from the set of available options, based on the impact of multiple, often conflicting, criteria is called Multiple Criteria Decision Making (MCDM). Over time, many MCDM methods have been formed, such as: SAW, ELECTRE, PROMETHEE, AHP, TOPSIS, COPRAS, VIKOR, MOORA, and so on.

Performance ratings of alternatives and criteria weights, in the mentioned ordinary MCMD methods, are expressed by using crisp values (ordinary numbers). Therefore, these methods have not been adequate to deal with some real-world problems.

Bellman and Zadeh (1970) were the first researchers in the field of decision making using fuzzy sets, who also initiated the fuzzy multi-attribute decision making (FMADM) methodology. Since then, a number of MCDM methode get their fuzzy extensions.

3.1. Compromise programming

The concept of Compromise programming was proposed by Zeleny (1973) and Yu (1973). The basic idea of this MCDM method is to determine the alternative that has the least distance from the reference point.

For a multiple criteria decision making problem which include *m* alternatives that are evaluated on the basis of *n* criteria, Compromise programming can be presented as follows:

$$\min L_{p,i} = \left\{ \sum_{j=1}^{n} w_j^p \left(\frac{x_j^* - x_{ij}}{x_j^* - x_j^-} \right)^p \right\}^{1/p}, \tag{1}$$

where $L_{p,j}$ is distance metric of *i*-th alternative for a given parameter *p*, w_j is the weight of *j*-th criterion, x_j^* and x_j^- are the best and the worst value of *j*-th criterion, respectively, x_{ij} is performance ratings of *i*-th alternative on *j*-th criterion, $i=1,2, \ldots, m$ and $j=1,2, \ldots, n$.

The parameter *p*, in formula (1) is used to represent the importance of the maximal deviation from the reference point. By varying the parameter *p* from 1 to infinity, it is possible to move from minimizing sums of individual deviations to minimizing the maximal deviation to the ideal point, in a decision-making process. The choice of a particular value of this compensation parameter *p* depends on the type of problem and desired solution (Yu 1973).

The best x_j^* and the worst x_j^- performance rating of *j*-th criterion are determined using the following formulae:

$$x_j^* = \begin{cases} \max\limits_i x_{ij}; & j \in \Omega_{\max} \\ \min\limits_i x_{ij}; & j \in \Omega_{\min} \end{cases}, \text{ and} \quad (2)$$

$$x_j^- = \begin{cases} \min\limits_i x_{ij}; & j \in \Omega_{\max} \\ \max\limits_i x_{ij}; & j \in \Omega_{\min} \end{cases}, \quad (3)$$

where $\Omega_{\max}$ and $\Omega_{\min}$ are sets of benefit and cost criteria, respectively.

The Compromise programming methodology has made a prominent use in the field of water resources management (e.g., Duckstein, Opricovic 1980; Simonovic, Burn 1989; Simonovic *et al*. 1992), but it is also applied in many other fields, such as forest management (Tecle *et al*. 1998; Poff *et al*. 2010) and economy (Andre *et al*. 1965).

In comparison to some currently very actual MCDM methods, such as TOPSIS, AHP and VIKOR, Compromise programming is rarely used. However, in this article we consider the use of a Compromise programming because it is simple to use and effective too.

3.2. Fuzzy Compromise programming

As previously stated, the use of crisp values, in the classical MCDM methods, has not provided opportunity for adequate solving the real-world problems.

Triangular fuzzy numbers, introduced by Zadeh (1965) provide the ability to deal with uncertainties, which characterize many real-world problems. Compared to the crisp numbers, fuzzy numbers enable creation of much more realistic models of complex problems and therefore the fuzzy MCDM approach has became the useful tool for solving many real world decision making problems.

Triangular fuzzy number (TFN) $\tilde{A}$, shown in Figure 1., is fully characterized by a triple of real numbers (*l*, *m*, *u*), where parameters *l*, *m*, and *u*, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event (Ertugrul, Karakasoglu 2009). The most promising value of TFN is often called mode or core.

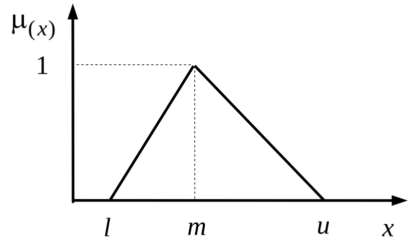

Fig. 1. Triangular fuzzy number

There are a number of possible fuzzy extensions of Compromise programming method, but for e-Commerce web site evaluation we propose use of the following formula:

$$\min \tilde{L}_{p,i} = \left\{ \sum_{j=1}^{n} w_j^p \left(\frac{\tilde{x}_j^* - \tilde{x}_{ij}}{x_j^+ - x_j^-} \right)^p \right\}^{1/p}, \tag{4}$$

where $\tilde{L}_{p,j}$ is fuzzy distance metric of *i*-th alternative for a given parameter *p*, $\tilde{x}_{ij}$ is fuzzy performance ratings of *i*-th alternative on *j*-th criterion, $\tilde{x}_{ij}^*$ is fuzzy reference point of *j*-th criterion, and $\tilde{x}_{ij}^+$ is the most preferable value of *j*-th criterion.

4. A framework for evaluation e-Commerce web site based on Fuzzy Compromise programming

Based on previous considerations, the procedure for evaluation of e-Commerce web sites can be expressed concisely using the following steps:

***Step* 1**: **Select key evaluation criteria and identify alternatives which will be ranked.** As in the case of using other MADM methods, our approach begins with the identification of available alternatives and by choosing the most important criteria.

For purpose of forming a simple and easy to use a framework we decided to use of a small number of criteria, but sufficient for adequate evaluation. These criteria are:

- **C_1 – Design of the Web site** (***D***). Web site design can significantly affect to acquisition of new customers, especially at beginners but also at ordinary Internet users. The first impression(s) which potential customer receives about a virtual store its based on it home page, or a quick examination of its web site. In the set of selected evaluation criteria, design of webpage is the first criterion, and it is very important because based on it some users make a decision about acceptance or rejection of an e-store.
- **C_2 – Easy to use** (***E***). **After** acceptance of a new web site users busily search for products or services they need, or trying to familiarize themselves with the complete range of products and services. The functionality of the web site, including an adequate system of menus, shortcuts (hyperlinks), a good search system and online help system, can greatly help to new users.
- **C_3 – Quality and availability of information** (***Q***). After finding the required products or services, quality and availability of a necessary information about them can also have a significant impact on obtaining a confidence of new customers.

- C_4 **– Ordering process** (***O***). Ordering is a step in which a potential customers become customers. Too complex or insufficiently flexible ordering process can lead to customers stop their ordering processes.
- C_5 **– Security assurance** (***S***). This criterion is very closely related with the above criterion, the ordering process, but we consider them separately. To complete the ordering process, a potential customer should to obtain a certain level of confidence, which assures that ordered products will be obtained without some kind of complications. The available payment options, delivery options, delivery tracking system and right to return and replacement may also significantly influence the opinions of potential customers.

Step **2**: **Determine weights of evaluation criteria**. The criteria weights have a very great significance in a MCDM models. Determining criteria weights based on the pairwise comparisons, adopted from the AHP method, is one of currently very actual approach. This procedure also has several important extensions that have been formed for it use in group and/or fuzzy environment.

This approach has been widely accepted, because it also has a mechanism for checking the consistency of performed pairwise comparisons. Based on that mechanism, if the consistency ratio (*CR*) has a value of less than 10%, the comparison was made consistently.

For a MCDM problem which *n* criteria and *K* decision makers, the procedure for determining the weight of criteria can be expressed by using the following formula:

$$w_i^k = \left(\prod_{j=1}^{n} a_{ij}^k \right)^{1/n} \Bigg/ \sum_{i=1}^{n} \left(\prod_{j=1}^{n} a_{ij}^k \right)^{1/n} , \tag{5}$$

where w_i^k is weight of *i*-th criterion which reflects the attitude of *k*-th decision maker , a_{ij}^k is relative importance of criterion C_i in relation to criterion C_j obtained on the basis of pairwise comparisons performed by *k*-th decision maker, $i=1,2,\ldots,n$; $j=1,2,\ldots,n$ and $k=1,2,\ldots,K$.

As a result of using formula (5) in the group containing *K* decision makers we also have *K* different criteria weights. In order to determine the resulting criteria weights we propose the use of the following formula:

$$w_j = \left(\prod_{k=1}^{K} w_j^k \right)^{1/K} , \tag{6}$$

where w_j^k is the relative criteria weight of *j*-th criterion obtained on the basis of pairwise comparisons of the *k*-th decision maker, and w_j is criteria weight of *j*-th criterion.

***Step* 3: Perform evaluation of alternatives in relation to a set of chosen evaluation criteria.** For evaluation of alternatives, we use less experienced Web users. After a detailed introduction to the meaning of selected evaluation criteria, they were asked to, using assessment scale from 1 to 10, perform evaluation of the proposed web sites.

For a group containing *K* evaluators, the resulting fuzzy performance ratings of alternative in relation to the criteria can be determined using the following formulae:

$$x_{ijl} = \min_k x_{ij}^k, \tag{7}$$

$$x_{ijm} = \left(\prod_{k=1}^{K} x_{ij}^k \right)^{1/K}, \text{ and} \tag{8}$$

$$x_{iju} = \max_k x_{ij}^k, \tag{9}$$

where $\tilde{x}_{ij} = (x_{ijl}, x_{ijm}, x_{iju})$ denote fuzzy performance rating of alternative i-th alternative to the *j*-th criterion, x_{ijl}, x_{ijm}, x_{iju} denotes the smallest possible value, the most promising value, and the largest possible value of fuzzy performance rating *i*=1,2,…,*m* and *m* is the number of alternatives, *j*=1,2,…,*n* and *n* is the number of criteria, *k*=1,2,…,*K*, and *K* is the number of decision makers.

***Step* 4: Calculate fuzzy overall performance index, for each alternative**. Calculation of fuzzy overall performance index of each alternative, for a given value of the parameter *p*, we perform using formula (4), as follows:

$$\tilde{S}_{p,i} = \left\{ \sum_{j=1}^{n} w_j^p \left(\frac{\tilde{x}_j^* - \tilde{x}_{ij}}{x_j^+ - x_j^-} \right)^p \right\}^{1/p}, \tag{10}$$

where $\tilde{S}_{p,i}$ is fuzzy overall performance index of *i*-th alternative.

***Step* 5: Rank alternatives and determine their relative distance from the best ranked.** In order to prank alternatives their fuzzy performance indexes should be transformed into the corresponding crisp numbers. In the case of evaluating performances of e-Commerce web sites, for transforming the fuzzy into crisp overall performance indexes we propose the use of the following formula (Chiu, Park 1994):

$$gm(\tilde{A}) = \frac{1}{3}(l + m + u) + \lambda m, \tag{11}$$

where $gm(\tilde{A})$ denote crisp mean of fuzzy number $\tilde{A}$, λ as a coefficient by which the decision maker can express his opinion about nature and importance of TFN mode, and $\lambda \geq 0$.

Because that in a proposed framework, left and upper boundaries of fuzzy overall performance indexes represents highly pessimistic or optimistic decision maker's attitudes, formula (11) provides ability to assign different significance to mode of a fuzzy performance indexes, which represents the most realistic attitude.

By varying values of λ decision maker can to give more importance to extreme (λ=0) or to realistic (λ=1) attitudes, and based on that consider different scenarios.

Finally, for the selected value of the parameter p and coefficient λ, using (10) and (11) can be determined overall performance indexes of alternative, as follows:

$$S_i = gm(\tilde{S}_{p,i}) \tag{12}$$

where S_i denote (crisp) overall performance indexes of ***i***-th alternative.

The considered alternatives are ranked by descending order of S_i, i.e. the alternatives with lower values of S_i have a higher priority (rank). Determination of the most appropriate alternative, A^*, can be done by using the following formula:

$$A^* = \left\{ A_i \mid \min_i \; S_i \right\}. \tag{13}$$

For the comparison of considered alternatives, except the overall performance index, we also use the relative performance index. To determine the relative performance index Q_i, we use the following formula:

$$Q_i = \frac{S_i^- - S_i}{S_i^- - S_i^*} 100 , \tag{14}$$

where $S_i^* = \min_i S_i$ and $S_i^- = \max_i S_i$.

5. A numerical example

To show the effectiveness of the proposed framework in this section we present the partial results taken from an initial study that was conducted to determine the quality of web sites of some e-Commerce companies in Serbia.

Determination of criteria weight was done by using pairwise comparisons procedure, as shown in the proposed framework. The following tables shows the data used for pairwise comparisons, obtained on the basis of opinions of three Internet specialists.

Table 1. The pairwise comparisons matrix and criteria weights obtained from the first Internet specialist (Source: compiled by author)

Criteria		***D***	***E***	***Q***	***O***	***S***	w_i
C_1	***D***	1	3	1/5	1	1/7	0.10
C_2	***E***	1/3	1	1	1/5	1/7	0.05
C_3	***Q***	2	1	1	1	1/9	0.10
C_4	***O***	1	5	1	1	1/5	0.13
C_5	***S***	7	7	9	5	1	0.62
		CR = 0.08 (8.36%) < 10%					

Table 2. The pairwise comparisons matrix and criteria weights obtained from the second Internet specialist (Source: compiled by author)

Criteria		***D***	***E***	***Q***	***O***	***S***	w_i
C_1	***D***	1	1/5	1/5	1/6	1/7	0.04
C_2	***E***	5	1	1	2	5	0.34
C_3	***Q***	5	1	1	1	3	0.27
C_4	***O***	6	1/2	1	1	3	0.24
C_5	***S***	7	1/5	1/3	1/3	1	0.11
		CR = 0.08 (8.65%) < 10%					

Table 3. The pairwise comparisons matrix and criteria weights obtained from the third Internet specialist (Source: compiled by author)

Criteria		***D***	***E***	***Q***	***O***	***S***	w_i
C_1	***D***	1	1/7	1/3	1/5	1/7	0.04
C_2	***E***	7	1	1	1	1/3	0.17
C_3	***Q***	3	1	1	1/3	1/5	0.10
C_4	***O***	5	1	3	1	1/5	0.18
C_5	***S***	7	3	5	5	1	0.51
		CR = 0.09 (9.03%) < 10%					

Based on the criteria weights obtained from three Internet specialists, the resulting criteria weights are calculated using formula (6). The resulting criteria weights are shown in Table 4.

Table 4. The resulting criteria weights (Source: compiled by author)

Criteria		w_j
C_1	***D***	0.05
C_2	***E***	0.15
C_3	***Q***	0.14
C_4	***O***	0.18
C_5	***S***	0.32

The data obtained on the basis of evaluation web sites obtained from three respondents are shown in Table 5.

Table 5. The data obtained from respondents (Source: compiled by author)

	First respondent					Second respondent					Third respondent				
	D	***E***	***Q***	***O***	***S***	***D***	***E***	***Q***	***O***	***S***	***D***	***E***	***Q***	***O***	***S***
A_1	8	8	7	9	8	7	5	4	7	7	6	7	7	8	7
A_2	5	8	4	6	6	3	5	5	6	6	3	7	5	6	6
A_3	8	6	4	8	8	5	4	7	6	6	3	6	7	7	5
A_4	7	6	9	8	8	6	4	8	9	8	4	7	7	9	9
A_5	6	7	8	9	8	6	4	8	7	6	5	8	8	6	5

Fuzzy performance ratings obtained by using formulae (7), (8) and (9) are shown in Table 6.

Table 6. The fuzzy performance ratings (Source: compiled by author)

	D	***E***	***Q***	***O***	***S***
A_1	(6, 6.95, 8)	(5, 6.54, 8)	(4, 5.81, 7)	(7, 7.96, 9)	(7, 7.32, 8)
A_2	(3, 3.56, 5)	(5, 6.54, 8)	(4, 4.64, 5)	(6, 6, 6)	(6, 6, 6)
A_3	(3, 4.93, 8)	(4, 5.24, 6)	(4, 5.81, 7)	(6, 6.95, 8)	(5, 6.21, 8)
A_4	(4, 5.52, 7)	(4, 5.52, 7)	(7, 7.96, 9)	(8, 8.65, 9)	(8, 8.32, 9)
A_5	(5, 5.65, 6)	(4, 6.07, 8)	(8, 8, 8)	(6, 7.23, 9)	(5, 6.21, 8)

Based on data from Tables 4 and Table 6, using formula (10) and for p = 2, the fuzzy overall performance indexes are calculated, as shown in Table 7.

Table 7. The overall ranking index and the ranking order of the considered alternatives (Source: compiled by author)

	$\tilde{S}_i$			S_i	Rank	Q_i
	l	***m***	***u***	(λ=0.5)		
A_1	0.02	0.01	0.01	0.14	2	94.96%
A_2	0.47	0.15	0.14	0.57	4	40.58%
A_3	0.88	0.51	0.25	0.89	5	0.00%
A_4	0.09	0.02	0.02	0.23	3	84.58%
A_5	0.01	0.01	0.01	0.10	1	100.00%

The overall performance index and the relative performance index of considered alternatives are given in table 7. The ranking order of the considered alternatives also is given in the Table 7.

As can be seen from Table 7, for λ= 0.5, the alternative A_5 is best ranked, and the alternatives A_1 takes second place. Using the relative performance index decision maker can better to determine how much is an alternative better than other alternatives.

6. Conclusions

This paper presents a relatively simple to use and effective framework for evaluation of e-Commerce web sites' performance, based on fuzzy Compromise programming method.

Using the proposed framework decision makers, or managers, in e-Commerce companies can check the performance of theirs web site, and on the basis of that take actions that will increase the performance of their web sites, and thus make their companies more competitive.

In Serbia, the e-Commerce currently has a very rapid development. Managers of e-Commerce companies that recognize the importance of web sites quality can achieve significant benefits in a competitive environment. The proposed model provides to decision makers in e-commerce the significant support in obtaining competitive advantages.

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