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On the Factors of Successful e-Commerce Platform Design during and after COVID-19 Pandemic Using Extended Fuzzy AHP Method

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Abstract: The ongoing COVID-19 pandemic has caused a paradigm shift in all aspects of contemporary human life. Everyday activities such as shopping have shifted from traditional methods to the ever-more growing online variants, allowing for an increase in electronic commerce (e-commerce) industry. As more services become available online, consumers often rely on trusted services, which are often reflected on the web and mobile platforms they are presented on. In this paper, we study the factors for successful e-commerce platform design in the Western Balkans region using Fuzzy Analytical Hierarchy Process (FAHP) with triangular fuzzy numbers. After an extensive literature overview, interviews with representatives of top-ranking e-commerce companies in the region, and the analysis of experts' opinions, we select a number of factors and sub-factors for prioritization, taking into account pre-pandemic factors, as well as the ones of the pandemic itself. We extend the FAHP model, which now consists of five (instead of three) points of view. Finally, we present and discuss the results in the form of tables and graphs, as well as an overall recommendation of what should be taken into account when designing an e-commerce platform. Our results rank service quality and security factors first and criteria such as multilingual support last.

Keywords: B2C e-commerce; Fuzzy AHP; MCDM; pandemic

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1. Introduction

In the last 20 years, in the era of new technologies and modernization, Internet use has increased significantly, especially for the purposes of communication, marketing, and electronic commerce (e-commerce) [1,2]. Business of marketing has always been fluid, continuously adapting to ever-evolving consumer preferences. The migration from traditional to electronic commerce was going on long before the events caused by the COVID-19 pandemic, which has only hastened this transition. Indeed, the need for commerce digitization rapidly graduated for many businesses into means for survival once the pandemic hit. Within a matter of weeks to months, brands without online options were hastily implementing new e-commerce platforms, and those already using digital infrastructures were bracing their servers' capacities for the impact of increased online traffic. E-commerce is defined as a type of Internet use mainly to carry out business transactions in which parties communicate electronically instead of in person. These transactions significantly reduce costs, save time, increase profits, and simplify business activities, involving manufacturers, consumers, and service providers that use the Internet [3,4]. There is a clear expectation from consumers that companies should do their part to help them in their daily lives and to keep them informed. Brands must be able to meet consumers where they are and offer personalized services for their specific needs. According to Shaw [5], considering the nature of transactions, there are five major categories of e-commerce: Business to Business (B2B), where e-commerce is done exclusively between companies; Business to Customer (B2C), in which company offers services to consumers; Business to Government (B2G), where companies offer government agencies products and services through online marketing and bidding for projects; Consumer to Business (C2B), where companies tender for projects posted by consumers; and Consumer to Consumer (C2C), where consumers sell their products to consumers online.

Knowing that B2C websites, where consumers directly buy products, present the lifeblood of B2C e-commerce, companies strive to design a successful B2C website and to ultimately make business considerably practical and effective. Amazon and Alibaba, followed by eBay, Walmart, Priceline, and Rakuten, are the most dominant and significant B2C e-commerce companies [6]. The popularity and expeditious advancement of B2C e-commerce make these sorts of transactions the leading retailing channel for ordinary customers [7], and therefore Internet-based commerce in general raises the question of awareness and vulnerability of consumers' privacy and security on B2C platforms [8–10]. Security and privacy of information provided by customers are very important, especially in risky and unpredictable ambiance [11]. Factors such as transaction confidentiality, integrity, and authentication imply trust at the technology level. For the continual performance of B2C online commerce, customer relationship management plays an important role [12] and trust becomes an inevitable factor [13,14].

In recent years, multi-criteria decision-making (MCDM) has been applied in various fields of scientific research in cases where it is desirable to restructure a multi-criteria problem. At the end of this process, the most optimal choice, or an alternative one, is selected. A formal framework for modeling multidimensional decision-making problems is therefore provided by applying MCDM, especially for problems that require systems analysis, the analysis of decision complexity, the relevance of consequences, and the need for the accountability of decisions made [15]. Utilizing Fuzzy MCDM (F-MCDM), an efficient approach for evaluating multiple criteria, can be achieved to support managers, experts, and other decision makers with the goal of balancing and measuring different factors, simplifying and clarifying decisions [16].

In this paper, we study the factors for successful e-commerce platform design using Fuzzy Analytical Hierarchy Process (FAHP) based on triangular fuzzy numbers [17]. In many real-world situations, when applying decision-making approaches, human judgment alone is often insufficient and not reliable. Therefore, the use of triangular fuzzy numbers presents a viable alternative for expert judgment regarding the qualitative factors and their importance. Similarly, trapezoidal, Pythagorean, z-numbers, and the recently introduced Spherical fuzzy numbers [18] may also be considered when applying the FAHP method. Although our research is based solely on triangular fuzzy numbers, we present an extension to the current model of optimism indexes. Firstly, we conduct a literature overview, and afterwards we select a number of factors and sub-factors for prioritization, taking into account factors during the COVID-19 pandemic. As a starting point, we include FAHP with three points of view and further extend to a novel, five-points-of-view ranking of sub-criteria.

The advances in this paper are summarized in the following:

- New sub-criteria influencing e-commerce websites are introduced.
- The FAHP method is extended by introducing two new points of view for the decision-maker, namely, semi-pessimistic and semi-optimistic views, with corresponding optimism indexes $\lambda = 0.25$ and $\lambda = 0.75$, respectively.
- The estimation and analysis of ranking similarities in the extended model is conducted and discussed.

As of writing this paper, the authors have not found any article or study regarding e-commerce platform design using FAHP in the region of the Western Balkans. Therefore, our main goal is to provide insights to the decision-making process and further extend one of the well-known MCDM methods. According to this goal, we formulated four research questions (RQs).

RQ1: Can the results presented in our paper help e-commerce companies of the Western Balkans region?

RQ2: Does a highly influencing sub-factor during the COVID-19 pandemic exist?

RQ3: Are there significant changes in the sub-factors ranking when the three values of an optimism index in the FAHP method are expanded to the finite or countable set of values?

RQ4: Do we have complete insight into the interrelations of sub-criteria using Extended FAHP?

The rest of the paper is organized as follows. Section 2 presents the criteria for evaluation of B2C websites, divided into factors and sub-factors. Section 3 deals with methodology used, namely, Fuzzy AHP. Finally, Section 4 gives the results, while the concluding remarks are given in Section 5.

2. Criteria for Evaluation of B2C Websites

In this Section, we firstly give a literature overview on the application of MCDM. Afterwards, we identify the main factors for the design of B2C e-commerce websites.

2.1. Literature Overview

In the past two decades, the application of MCDM and some other approaches in the process of evaluation of B2C e-commerce-website-related tasks has led to a number of published works. These approaches include but are not limited to Analytical Hierarchy Process (AHP) [14,19–21], Analytical Network Process (ANP) and Grey Relational Analysis (GRA) [22], fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [23], VIsekriterijumska optimizacija i KOmpromisno Resenje (VIKOR) [15], fuzzy VIKOR [24], Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE) [25], and PROMETHEE for Sustainability Assessment (PROSA) [26]. In addition, the Decision-making Trial and Evaluation Laboratory (DEMATEL) [27,28] is also a very convenient method for assessing the B2C websites criteria. Service quality has been the main aim of the majority of online platforms [29], with emphasis on the difference between levels of perceived and expected service [30]. Customer orientation, marketing, and security have been the most important factors in evaluation of five-star hotel websites in Mashhad, according to the research conducted by Ostovare and Shahraki [25], while price saving, awareness, and security took precedence in the assessment of the website quality of the Turkish e-business market [31]. In [32–34], content quality, service quality, and system availability, followed by security, ease usage, privacy, efficiency, and appearance, have been influence factors in the prioritization of B2C e-commerce websites. Similar investigations of the influence and relevance of each website quality factor have been discussed by Del Vasto-Terrientes et al. [35], Dey et al. [36], and Chou and Cheng [37]. However, there have been other relevant papers with a different viewpoint . For example, Ashraf et al. [7] have dealt with the connection between e-commerce business and their customers; Kang et al. [38] have introduced new E-S-QUAL based TOPSIS approach for evaluation of e-commerce websites; and Ong and Teh [39] have focused on consumer expectations, complaints, and compensations.

Recent studies have dealt with applying MCDM methods for better decision making. For instance, in [16], the authors deal with delivery time, order fulfillment, convenience of payment, and real-time tracking, and their influence on Last Mile Delivery companies utilizing FAHP with triangular fuzzy numbers. They conclude that utilizing MCDM techniques can be valuable for both researchers and decision-makers themselves. In [40], the authors combine data envelopment analysis and Grey model, with the goal of predicting and assessing future efficiency in e-commerce marketplaces. Finally, in [41], the authors apply triangular fuzzy numbers for FAHP, coupled with TOPSIS-Grey techniques to, respectively, determine factors and access alternatives for B2C e-commerce websites.

2.2. Main Factors for B2C e-Commerce Websites

In this paper, we have identified five major factors with corresponding sub-factors for the design of B2C e-commerce websites. The initial factors and sub-factors were obtained from the extensive literature overview given in Section 2.1. Furthermore, we have selected the top-ranking companies from the Western Balkans Region and interviewed their representatives from sales, management, and IT support sectors [42]. These companies' activities mainly deal with consumer products, with a couple of them having an e-Bay like business model. A total of 23 persons representing both companies' points of view, and customers' experience, responded to our interviews. Finally, four experts in the fields of mathematics, artificial intelligence, digital marketing, and management have acknowledged all given answers, and have, in consensus with the authors, obtained the final list of factors and their respective sub-factors.

The opinions we have collected from the representatives of e-commerce companies, professionals, and ourselves as the authors, as well as the selection and ranking of criteria and sub-criteria, will be useful to the managerial part of companies in meeting various challenges posed by the ongoing COVID-19 pandemic, as well as the challenges that will come after.

The summary of each of the main factors with corresponding sub-factors is given in Figure 1, while the detailed descriptions of each are presented below.

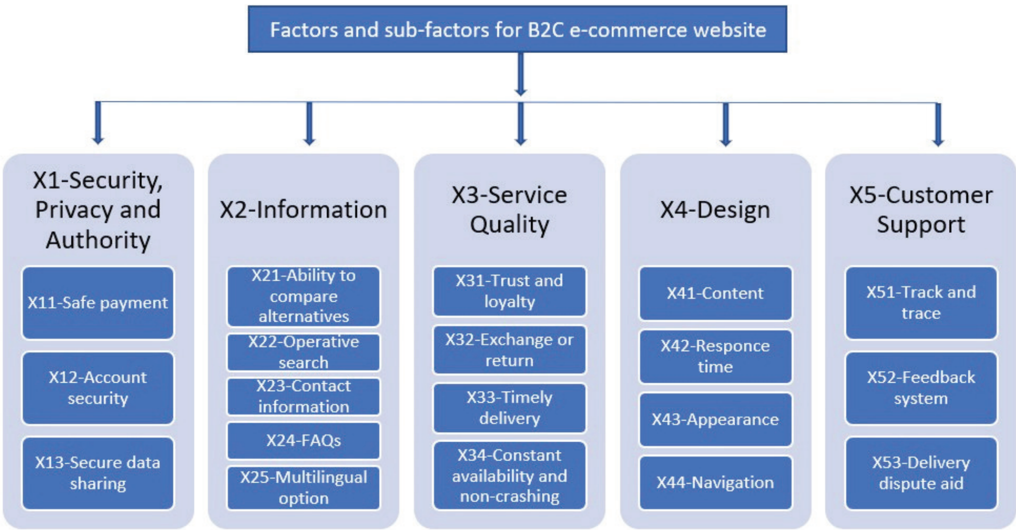

Figure 1. Factors and sub-factors for B2C website.

2.2.1. *X*1: Security, Privacy and Authority

Security is a dominant concern for all types of e-business web sites [43]. The presence of the somewhat insecure networks and/or servers can lead to the corruption and exploitation of customers' personal data. A company's reputation heavily relies on this type of vulnerability,, and potential attackers should not be able to have access to customers' information by accessing their databases or websites. When customers have to worry about the process of collection and maltreatment of personal information, trust towards online shops decreases [44]; Conversely, if the impression of being secure while browsing a B2C website persists, confidence and trust towards the website increases. When dealing with online payment, companies should accept well-known payment methods as well as globally recognized credit cards, in order to preserve customers' credit card information to an online account and ultimately ensure safety [10]. As soon as the pandemic shopping trends started [42], website security became paramount.

2.2.2. *X*2: Information

Every customer on the e-commerce website should be able to contact the company for any necessary information and/or regarding disputes [45]. The existence of company contact details also helps in solving problems and contributes to the level of confidence [46]. It is important to have correct and updated information of item availability, a search by keyword options, and the option to compare multiple items' characteristics [34,47]. Having a version of the website in other languages is mandatory nowadays, especially for those websites trading on a global scale. A section for Frequently Asked Questions or similar step-by-step guides can also be useful, especially for new shopper influx due to the pandemic.

2.2.3. *X*3: Service Quality

Every e-commerce website should be trustworthy. Since e-trust has a positive affect on e-loyalty, and a pleased customer often refers new potential buyers to shops, trust is essential for continual success in long-term online business [48,49]. The constant availability of websites, especially well-known ones, is recommended, with no down-time. In addition, a B2C website's significance and influence are also determined by the purchased items' delivery time, and multiple delivery options should exist [50], with a no-contact delivery option as well. There should be no delays in the process of delivery, nor should delivery schedules change often, as they have a negative influence on e-satisfaction [51]. The opportunity for item replacement or return enhances the number of customers and helps to solve any potential conflicts between the buyer and the company [39].

2.2.4. *X*4: Design

Online shops' long-term profitability will be strengthened by their content [52]. If the customer is bored by the content of the site, its non-creativeness; or the lack of applications, images, and/or data, or they have difficulties in finding necessary information, the sales potential will be significantly reduced [25,34]. Therefore, according to Ivory [53], good navigation is fundamental, and it should consist of clear and helpful links. Additionally, the appearance on the B2C e-commerce website must be attractive and well-organized, always keeping the customer's attention and encouraging them to come back [32]. Page load and response times should be as short as possible, because if it takes long to load or download the page (e.g., due to many graphic elements), the site's performance will suffer [54]. Customers' satisfaction will increase if the company's staff is responsible, enthusiastic, and happy to give quick responses to queries and provide help [55].

2.2.5. *X*5: Customer Support

It would be desirable for the B2C e-commerce website to include a customer support service as people need to know the status of the purchased item, whether their order is still in the warehouse, or whether it is being delivered [33,50]. The option of product reviews should be available to customers, and they should include realistic feedback about the negative and/or positive aspects of the service [32,56]. Reimbursement is often a subject of discussion or dispute, so B2C e-commerce should provide a help service for these types of situations [57]. One of the essential factors for a successful business is its communication method with online consumers, meaning that quick and adequate information should be provided by the company in order to increase the return visits by customers [58].

3. Methodology

The fuzzy set theory has been known for over half a century, ever since its proposal by Zadeh in 1965. Even then, it has been employed as guidance for fuzzy decision-making problems. Their original inception was intended for linguistics, and it has enabled uncertainty and imprecision to be represented, and, more importantly, constructed in a deterministic manner [59,60]. Sets defined in such a manner could therefore be identified as a generalization of the well-known set theory, enabling a decision-maker to include incomplete or partially unknown information in the decision model [61].

Whereas in the classic set theory, an element can either belong to a set or not belong at all, in fuzzy sets, the membership of an element can be described by a number from the interval $[0,1]$. Each element of this set can hence be mapped on this interval with a membership function (MF), denoted by μ. In addition, a fuzzy set can have an infinite number of different MFs.

Let all fuzzy sets defined on the set of real numbers $\mathbb{R}$ be represented as $F(\mathbb{R})$. The number $A \in F(\mathbb{R})$ is a fuzzy number if there exists $x_0 \in \mathbb{R}$ so condition $\mu_A(x_0) = 1$ holds, and $A_\lambda = [x, \mu_{A_\lambda}(x) \geq \lambda]$ is a closed interval for every $\lambda \in [0,1]$ $\big($see [17,62]$\big)$. The membership function, a component of a triangular fuzzy number (TFN) A, is a function $\mu_A : \mathbb{R} \to [0,1]$, defined as

$$\mu_F(x) = \begin{cases} \dfrac{x-l}{m-l}, & l \leq x \leq m, \\ \dfrac{u-x}{u-m}, & m \leq x \leq u, \\ 0, & \text{otherwise}, \end{cases} \tag{1}$$

where inequality $l \leq m \leq u$ holds. Variables l, m, and u are the lower, middle, and upper value, respectively, and when $l = m = u$, TFN becomes a crisp number. In the sequel, the triangular fuzzy number will be denoted by $\tilde{A} = (l, m, u)$.

Assume two TFNs, $\tilde{A}_1 = (l_1, m_1, u_1)$, $\tilde{A}_2 = (l_2, m_2, u_2)$, and scalar $k > 0, k \in \mathbb{R}$. The arithmetic operation properties are defined as [63–65]:

Addition:

$$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2), \tag{2}$$

Subtraction:

$$\tilde{A}_1 \ominus \tilde{A}_2 = (l_1, m_1, u_1) \ominus (l_2, m_2, u_2) = (l_1 - u_2, m_1 - m_2, u_1 - l_2), \tag{3}$$

Multiplication:

$$\tilde{A}_1 \otimes \tilde{A}_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 \cdot l_2, m_1 \cdot m_2, u_1 \cdot u_2), \tag{4}$$

Reciprocal:

$$\tilde{A}_1^{-1} = (l_1, m_1, u_1)^{-1} = (\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}), \tag{5}$$

Scalar multiplication:

$$k \cdot \tilde{A}_1 = k \cdot (l_1, m_1, u_1) = (k \cdot l_1, k \cdot m_1, k \cdot u_1). \tag{6}$$

Left and right side of the membership function of triangular number $\tilde{A} = (l, m, u)$, as shown in Figure 2, are denoted by $\mu^l_{\tilde{A}} = \dfrac{x-l}{m-l}$ and $\mu^r_{\tilde{A}} = \dfrac{u-x}{u-m}$, and their matching inverse functions are

$$\left(\mu^l_{\tilde{A}}\right)^{-1} = l + (m-l)y, \quad \left(\mu^r_{\tilde{A}}\right)^{-1} = u + (m-u)y, \quad y \in [0,1] \tag{7}$$

Left and right integral values of the triangular fuzzy number $\tilde{A}$, according to [66], are defined as

$$I_L(\tilde{A}) = \int_0^1 (\mu^l_{\tilde{A}})^{-1} dy = \int_0^1 (l + (m-l)y) dy = \frac{1}{2}(m+l), \tag{8}$$

and

$$I_R(\tilde{A}) = \int_0^1 (\mu^r_{\tilde{A}})^{-1} dy = \int_0^1 (u + (m-u)y) dy = \frac{1}{2}(m+u), \tag{9}$$

and the total integral value, according to [66] as a combination of left and right integral values, is

$$I_T^{\lambda}(\tilde{A}) = \lambda I_R(\tilde{A}) + (1-\lambda) I_L(\tilde{A}) = \frac{1}{2}\lambda(m+u) + \frac{1}{2}(1-\lambda)(m+l) = \frac{1}{2}(\lambda u + m + (1-\lambda)l), \quad (10)$$

where λ represents an optimism index. The pessimistic, semi-pessimistic, balanced, semi-optimistic, and optimistic points of view of the decision-maker are, respectively, expressed by the values 0, 0.25, 0.5, 0.75, and 1.

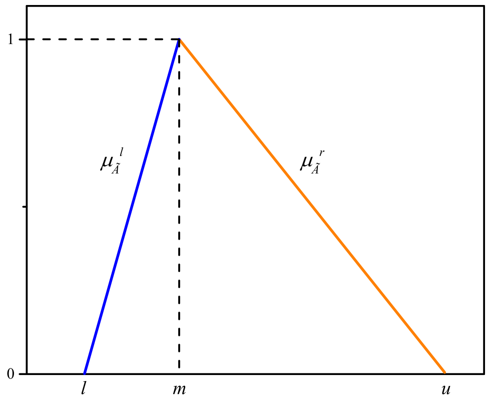

Figure 2. The representation of a triangular membership function.

Fuzzy AHP

Since its creation [67], the AHP had a respectable application in MCDM, enabling the decision makers to solve complex problems by decomposing them into a hierarchical structure, creating the comparison matrix and determining the importance of one indicator above others. The specified level of uncertainty of a team of experts (or even one expert) [68] due to the inability to express the significance of some criteria has led to the introduction of FAHP [69,70] enabling conversion of linguistic statements into mathematical expressions.

The summarized steps in FAHP are as follows [17,71]:

Step 1. Establishing the main goal and hierarchical appearance of criteria. In general, the hierarchical structure has been organized vertically: the main goal is, as the most important component, at the top; the criteria that contribute to the goal are at the intermediate levels; and the sub-criteria are at the lowest level.

Step 2. Determining the pairwise comparison matrix $\widetilde{D}$ in terms of TFNs. In this step, a positive fuzzy reciprocal comparison matrix $\widetilde{D} = (\tilde{d}_{ij})_{n\times n}$ with a total of $\binom{n}{2}$ comparisons of elements from a higher level with elements from a lower level is developed. The fuzzy value $\tilde{d}_{ij}$ represents the degree of relative importance between criteria; $i = j$, $\tilde{d}_{ij} = (1,1,1)$, and $\tilde{d}_{ij} = 1/\tilde{d}_{ji}$, otherwise. Table 1 shows the fuzzy scale for constructing pairwise comparisons.

Table 1. Marks, linguistic terms, and denotation of TFNs.

Mark	Linguistic Term	Denotation of TFNs	TFNs
E	Equal importance	$\tilde{1}$	$(1,1,3)$
AW	Absolutely weak dominance	$\tilde{2}$	$(1,2,3)$
EW	Extremely weak dominance	$\tilde{3}$	$(1,3,5)$
VW	Very weak dominance	$\tilde{4}$	$(3,4,5)$
FW	Fairly weak dominance	$\tilde{5}$	$(3,5,7)$
FS	Fairly strong dominance	$\tilde{6}$	$(5,6,7)$
VS	Very strong dominance	$\tilde{7}$	$(5,7,9)$
ES	Extremely strong dominance	$\tilde{8}$	$(7,8,9)$
AS	Absolutely strong dominance	$\tilde{9}$	$(7,9,9)$

As it was recommended in [72], a fuzzy distance of 2 and odd values as boundaries for all non-intermediate values are applied in order to achieve better consistency. There are also different scales of triangular fuzzy numbers applicable in the previous case [73–75].

The graphic representation of the used FAHP scale with all three values (lower, median, and upper) is presented in Figure 3.

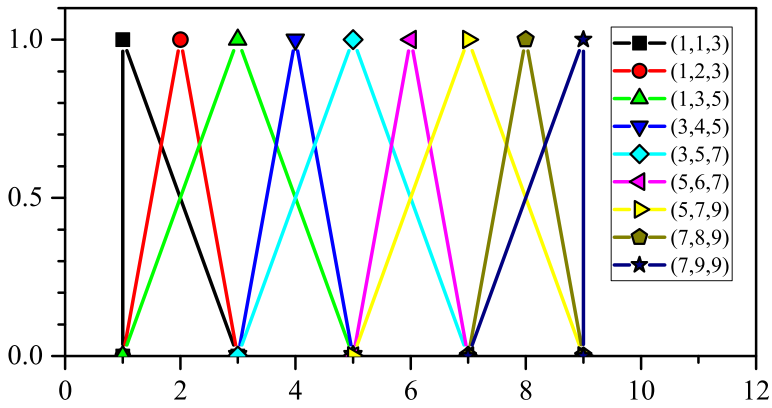

Figure 3. Graphic representation of TFNs.

Step 3. Matrix consistency review.

For a matrix $D = (d_{ij})_{n \times n}$, the consistency index CI and consistency ratio CR are calculated using eqs. from [76]:

$$CI = \frac{\lambda_{\max} - n}{n - 1}, \quad CR = \frac{CI}{RI}, \tag{11}$$

where $\lambda_{\max}$ corresponds to a maximal eigenvalue of matrices D and RI is a random index, as shown in Table 2.

Table 2. The table of Random Index numbers.

Matrix Dimension	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The value $CR < 0.1$ confirms the comparison matrix consistency, while otherwise the reason for inconsistency should be found and calculations repeated [77].

Step 4. The fuzzification process.

Using the triangular fuzzy numbers from the comparison matrix $\widetilde{D} = (\tilde{d}_{ij})_{n \times n}$, applying

$$A = \sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{d}_{ij} = \sum_{i=1}^{n}\sum_{j=1}^{n} (l_{ij}, m_{ij}, u_{ij}), \tag{12}$$

and

$$A^{-1} = \left(\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{d}_{ij}\right)^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} l_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} m_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} u_{ij}}\right), \tag{13}$$

the value of the fuzzy synthetic extent is obtained as follows [64]:

$$\widetilde{S}_i = \sum_{j=1}^{n} \tilde{d}_{ij} \otimes A^{-1} = \sum_{j=1}^{n} (l_{ij}, m_{ij}, u_{ij}) \otimes A^{-1}, \quad i = \overline{1, n}. \tag{14}$$

Step 5. The defuzzification process.

Next, in this step, using

$$w_i = I_T^{\lambda}(\widetilde{S}_i) = \frac{1}{2}\big(\lambda u_i + m_i + (1-\lambda)m_i\big), \lambda \in [0,1], i = \overline{1,n}, \tag{15}$$

the total integral value for the TFNs $\widetilde{S}_i$ is calculated [78].

Step 6. Normalization of weight vector w and obtaining the vector for each criterion. Using

$$w_i^* = w_i \left(\sum_{i=1}^{n} w_i \right)^{-1}, \tag{16}$$

the weights for all criteria are obtained.

Step 7. Ranking the weights for all sub-criteria.

The weights for each sub-criterion are obtained by multiplying the weights of the criteria and sub-criteria. Then, arranging the obtained weights, the sub-criteria ranking is received.

These steps can also be presented in algorithm form [79], shown below in Algorithm 1.

Algorithm 1 Steps in the FAHP process.

1: Establish the main goal
2: Identify Xi, Xij ▷ Criteria and sub-criteria
3: Construct **D** ▷ Fuzzy correlation matrix
4: Calculate CR
5: **if** $CR \geq 0.1$ **then**
6: Adjust values
7: **go to** 3
8: **else**
9: Fuzzification, calculate $\widetilde{S}_i$
10: Defuzzification, calculate w_i
11: Calculate w_i^* ▷ Normalization vector
12: Xij ranking
13: **end if**

One of the main general drawbacks of the AHP methods (FAHP included) is the existence of incomparable criteria. This shortcoming may be overcome using the network-like presented ANP, where all the criteria, sub-criteria, and alternatives are presented as nodes, grouped in clusters, enabling them to be compared to each other as long as an interrelation exists there. In this paper, we have chosen the FAHP method only, due to the fact that it enables the expert to decompose a complex problem into a few simplified steps. We have, however, extended the model to include five points of view instead of the usual three. The decision maker can hence easily express their opinion using descriptive grades, and these linguistic values can be further explained with a mathematical approach.

4. Results and Discussion

We firstly discuss the main criteria ranking, both for AHP and FAHP, with three points of view (pessimistic, balanced, and optimistic). Afterwards, we rank individual sub-criteria. Finally, we conduct the ranking of all nineteen sub-criteria using the extended FAHP, with semi-pessimistic and semi-optimistic points of view, and test our ranking using the Spearman rank correlation coefficient [80].

In the FAHP process, we have firstly calculated a fuzzy comparison matrix and weights for the main five criteria, as shown in Table 3, and since $CR = 0.008117 < 0.1$, the matrix is consistent.

Table 3. Fuzzy comparison matrix and weights for the criteria. ($CI = 0.009091$, $CR = 0.008117$).

	X3	X1	X4	X2	X5	AHP	FAHP		
							$\lambda = 0$	**$\lambda = 0.5$**	**$\lambda = 1$**
X3	1	AW	EW	VW	VW	0.412883117	0.400411317	0.375637961	0.365636296
X1	1/AW	1	AW	EW	EW	0.257090909	0.248161536	0.268051255	0.276081266
X4	1/EW	1/AW	1	AW	AW	0.15387013	0.163961943	0.165933156	0.166728987
X2	1/VW	1/EW	1/AW	1	E	0.088077922	0.098157381	0.105917923	0.109051062
X5	1/VW	1/EW	1/AW	1/E	1	0.088077922	0.089307823	0.084459704	0.082502389

In addition, the ranking of main criteria for both AHP and pessimistic, balanced, and optimistic FAHP points of view (with corresponding $\lambda = 0$, $\lambda = 0.5$ and $\lambda = 1$, respectively) is presented in Figure 4. In both AHP and all three FAHP cases, criteria $X3$-Service Quality ranked highest, while criteria $X5$ (customer support) ranked lowest. This is somewhat expected, as Quality of Service, and its superset Quality of Experience, are increasing factors in the Internet presence of B2C websites. This corresponds to the finding of [42] for the pandemic shopping trends. In AHP ranking, our results show that $X5$ and $X2$ have the same rank, while in all three cases of FAHP, no two criteria are ranked the same. Using FAHP, a decision-maker can fine-tune their actions to increase an aspect of their B2C website.

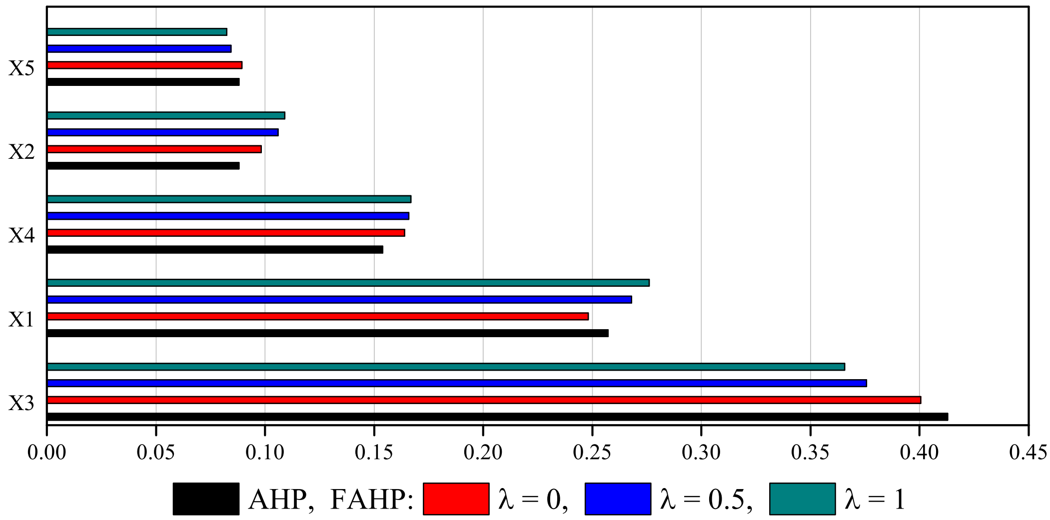

Figure 4. Ranking of main criteria.

Comparing points of view for main criteria, we can observe that a optimistic point of view (i.e., $\lambda = 1$) does not always yield a higher rank when compared to the pessimistic view. For instance, for $X3$ and $X5$, the highest and lowest criteria, the pessimistic point of view ranked higher when compared to the corresponding optimistic view.

The ranking of sub-criteria is firstly conducted in the same manner as the ranking of the main criteria, and fuzzy comparison matrices are given in Tables 4–8. The results show that all matrices are consistent. Similar to the main criteria comparison, the AHP method yields equal ranking in some cases, namely, in $X2$-Information. Out of five sub-criteria, we have two pairs of equal rankings, in the highest and second highest rank. This can also be observed in the triangular fuzzy numbers for $X2$ in Figure 5. Sub-criteria $X21$ and $X22$, corresponding to Comparison and Search functions, respectively, have equal ranking. These two sub-criteria both require customer input, and a B2C website with a better user-friendly design would most certainly aid in these functions. The second highest ranking pair, $X23$ and $X25$, referring to contact information and multilingual options, respectively, do not require user input like the previous case but rather serve to increase customers' trust in the company. Both groups are very important in the post-COVID world as e-trust, as stated in the introductory section, is an ever-increasing factor for B2C websites.

Similar to the main criteria case, FAHP distinguishes between sub-criteria; their rankings are unique, regardless of point of view.

Table 4. Fuzzy comparison matrix for the sub-criteria X1. ($CI = 0.01935734$, $CR = 0.033374725$).

X1	X11	X12	X13	AHP	FAHP		
					$\lambda = 0$	$\lambda = 0.5$	$\lambda = 1$
X11	1	EW	FW	0.63334572	0.599820738	0.591656755	0.588533901
X12	1/EW	1	EW	0.260497956	0.282085188	0.300366108	0.307358852
X13	1/FW	1/EW	1	0.106156324	0.118094074	0.107977137	0.104107247

Table 5. Fuzzy comparison matrix for the sub-criteria X2. ($CI = 0.006617$, $CR = 0.005908$).

X2	X21	X22	X23	X25	X24	AHP	FAHP		
							$\lambda = 0$	$\lambda = 0.5$	$\lambda = 1$
X21	1	E	EW	EW	VW	0.339857789	0.332148452	0.337465904	0.339522834
X22	1/E	1	EW	EW	VW	0.339857789	0.323512873	0.316376598	0.313616098
X23	1/EW	1/EW	1	E	AW	0.12354234	0.137948347	0.148733854	0.152905973
X25	1/EW	1/EW	1/E	1	AW	0.12354234	0.129312769	0.127644548	0.126999237
X24	1/VW	1/VW	1/AW	1/AW	1	0.073199741	0.07707756	0.069779096	0.066955858

Table 6. Fuzzy comparison matrix for the sub-criteria X3. ($CI = 0.017122$, $CR = 0.019024$).

X3	X31	X32	X34	X33	AHP	FAHP		
						$\lambda = 0$	$\lambda = 0.5$	$\lambda = 1$
X31	1	AW	EW	FW	0.470859052	0.423579259	0.432912498	0.436834883
X32	1/AW	1	AW	VW	0.284012522	0.312661857	0.289935851	0.280385026
X34	1/EW	1/AW	1	EW	0.171482932	0.184139706	0.202744493	0.210563335
X33	1/FW	1/VW	1/EW	1	0.073645495	0.079619178	0.074407158	0.072216756

Table 7. Fuzzy comparison matrix for the sub-criteria X4. ($CI = 0.01529$, $CR = 0.016989$).

X4	X42	X43	X41	X44	AHP	FAHP		
						$\lambda = 0$	$\lambda = 0.5$	$\lambda = 1$
X42	1	AW	EW	VW	0.45962704	0.444670919	0.432519768	0.427562099
X43	1/AW	1	AW	EW	0.294498834	0.276962234	0.291258588	0.297091501
X41	1/EW	1/AW	1	AW	0.157249417	0.175428777	0.176823909	0.177393123
X44	1/VW	1/EW	1/AW	1	0.088624709	0.10293807	0.099397735	0.097953278

Table 8. Fuzzy comparison matrix for the sub-criteria X5. ($CI = 0.009168629$, $CR = 0.01580798$).

X5	X51	X52	X53	AHP	FAHP		
					$\lambda = 0$	$\lambda = 0.5$	$\lambda = 1$
X51	1	EW	VW	0.623224728	0.598898685	0.602150325	0.603699288
X52	1/EW	1	AW	0.239487608	0.253851464	0.262713775	0.266935459
X53	1/VW	1/AW	1	0.137287664	0.147249851	0.1351359	0.129365254

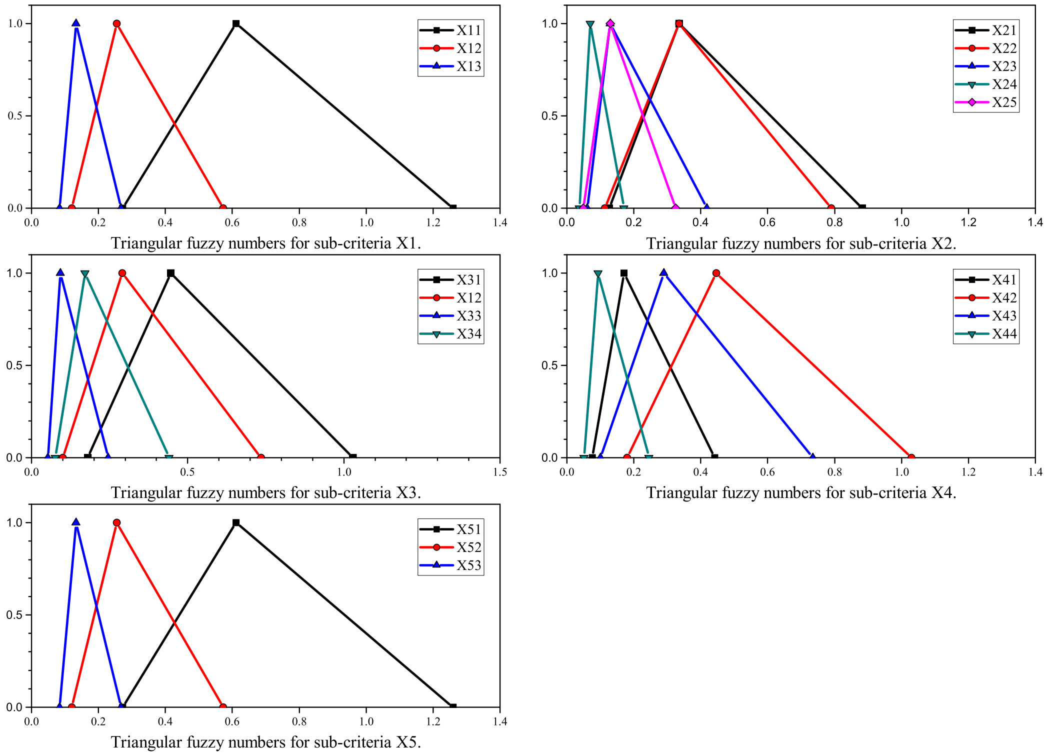

Figure 5. Triangular fuzzy numbers for criteria X.

Finally, we extend the process of FAHP by adding the semi-pessimistic ($\lambda = 0.25$) and semi-optimistic ($\lambda = 0.75$) points of view. The final ranking sub-criteria is given in Figure 6. We observe that while the sub-criteria from $X3$, namely $X31$, still ranked highest; however, the remaining sub-criteria from Service Quality, $X32$, $X34$, and $X33$ ranked third, fifth, and eleventh, respectively. Furthermore, the highest ranked sub-criteria from customer support, namely, $X51$, corresponding to item tracking, ranked seventh overall, is 2.6 times higher than $X52$ and 4.5 times higher for the AHP case and about 2.301 and 4.395 times higher in the FAHP case (averaged over all points of view). The high overall ranking of tracking and tracing reflects the shift in online transactions, which includes item delivery during the pandemic and, more importantly, in the post-COVID world .

We have applied different solving techniques in this paper, which can, in general, lead to inconsistencies or disagreement. For the purpose of estimation and analysis of ranking similarities applying the AHP and the Extended FAHP to all sub-criteria influencing e-commerce platforms, we have conducted fifteen different rankings using the Spearman rank correlation coefficient: [80]:

$$r_s = 1 - \frac{6\sum_{k=1}^{n}\left(R_{x_k} - R_{y_k}\right)^2}{n(n^2 - 1)}, \tag{17}$$

where n is the number of elements in the ranking and R_{x_k} and R_{y_k} represent the ranks of the k-th element in the compared rankings. By applying Equation (17), all compared results are presented in Figure 7, and since min $\{r_s\} = 0.964912$, it can be concluded that all rankings have high similarity [81].

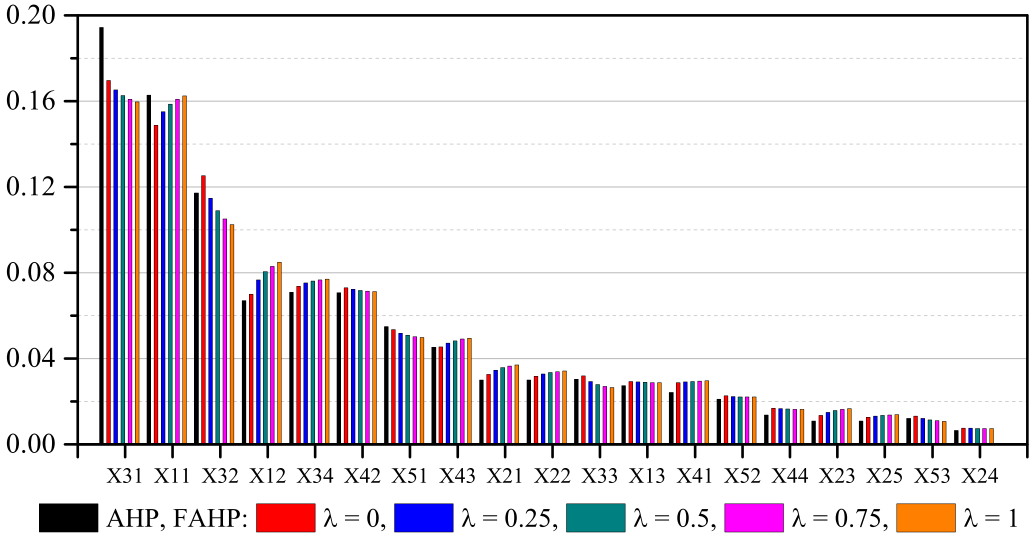

Figure 6. Final ranking of sub-criteria.

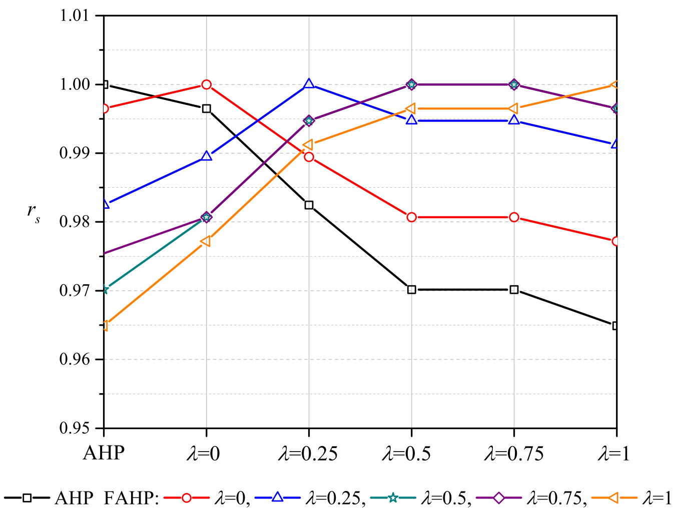

Figure 7. Ranking similarity.

5. Conclusions

Due to the ongoing pandemic, the previous two years have made a significant impact in all aspects of life—everyday activities, education, healthcare, security, economy, and trade, and have hence acclimated people to a new form of reality. Certain situations, such as lockdowns, paved the way for the ever-growing online presence. The struggle of small and medium enterprises to compete on the market therefore heavily relied on their shift towards online commerce. Reports that show multiple increments of online sales are an indicator that the trend of online commerce will continue to exist and grow in the post-COVID world.

The paper has investigated the problem of e-commerce management and the influence of various different factors. Indicators associated with digital platforms have been divided into five groups, involving security, information, quality, design, and support aspects. Using AHP and Extended FAHP, nineteen sub-criteria were ranked to determine the preferred ones in the process of e-commerce evaluation. The obtained results indicated that the proposed methods are entirely capable of estimating the influence of factors and sub-factors on online trade commerce. Considering the obtained weights for each sub-criteria and all five values of λ in the FAHP case, factors such as trust and loyalty, safe payment, exchange or return, and account security have the most significant effect on successful e-commerce platform design, while the FAQs, multilingual option, and contact information deemed the least significant. In the AHP case, the same sub-criteria from the service quality and security, privacy, and authority are ranked highest, while those from the information sector are of least importance.

Although our proposed method gives insight into several advantages and potentials in the field of B2C e-commerce, there are limitations to this work. However, these limitations might lead to future possibilities and steps forwards in our future research. Our use of AHP, because of its top-down direction structure and comparisons of criteria from one level with all criteria from the upper level, can lead to incomparable sub-criteria. This challenge can be overcome utilizing ANP, which allows clusters and elements, as well as interactions between the elements of hierarchy. This approach can further lead to more accurate results in the sub-criteria comparisons.

Another limitation presents the impossibility to examine the market solely from the customers' point of view, which was the main reason for conducting interviews with experts in management and sales from companies with a range of up to two million clients. Based on their experience in e-commerce companies, we have obtained the requirements and experts' judgments related to e-commerce businesses similar to those given by their clients.

The findings in this paper present a starting point for our continual research in the e-business area. Depending on the type of e-business and/or e-trade, we plan to add or remove certain factors or sub-factors. Furthermore, an extension to this research could focus on the practical application for the ranking of the alternatives of given websites. Finally, various MCDM methods, such as AHP, TOPSIS, and VIKOR, could be applied with fuzzy logic, Pythagorean fuzzy numbers, Intuitionictic fuzzy numbers, z-Numbers, and/or Spherical fuzzy numbers.

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