7th European Conference on Industrial Engineering and Operations Management
Augsburg, Germany, July 16-18, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/EU07.20240194
Published: July 16, 2024

Evaluation of Online Shopping Sites Using Industry 4.0 Solutions with the Simple Additive Weighting Method Using Spherical Fuzzy Sets: A Case of Türkiye

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Abstract

Online shopping sites, which have been integrated into our lives through the Internet, one of the most important inventions in human history, makes people's lives easier and evolving day by day. Therefore, consumers and businesses have turned to online shopping sites for convenience and sustainability. The aim of the study was to rank some online shopping sites in Türkiye by examining online shopping preferences in a fuzzy environment based on Industry 4.0. For this purpose, spherical fuzzy sets and integration with Simple Additive Weighting were used to determine the importance weights of the criteria and the ranking of the shopping sites. The results show that the most popular shopping website also ranks first in our ranking.

Keywords
Industry 4.0, Fuzzy Logic, Online Shopping, Spherical Fuzzy Sets

1. Introduction
E-commerce, which forms the basis for online shopping sites, is defined by institutions and organizations from different perspectives. According to the Organization for Economic Co-operation and Development (OECD), e-commerce is broadly defined as individuals and organizations conducting commercial activities based on the transmission of digital data, including text, sound and images (Organization for Economic Co-operation and Development 2011). Online shopping, the most widespread form of e-commerce today, is a part of e-commerce and is defined as the purchase of products or services by consumers over the Internet without intermediaries (Cavlak 2012).

Online shopping can be defined in its simplest form as shopping on the Internet. Platforms that bring customers and sellers together online are called online shopping sites. Unlike traditional shopping, online shopping is beneficial to consumers who want to quickly access the products, services and variety they are looking for. Consumer interest in online shopping is increasing thanks to the benefits it offers, such as ease of use, 24/7 access, low prices, convenience, product variety and time savings (Durmaz and Aksakal, 2023). Considering the fact that the Internet is becoming more widely used as technology evolves, competition between online shopping sites will continue to increase in the face of rising consumer demand. In this competitive environment, those who follow the development of technology and improve their systems by attracting consumers' attention and ensuring its continuity will have an advantage over their competitors.

The process that begins with the new world order created by new technologies is called the fourth stage of industrialization, namely Industry 4.0. The simplest definition of this new era, namely Industry 4.0, is defined as the "Internet of machines, computers, people and things"(Annunziata 2012). In this context, by using Industry 4.0, companies will be able to become competitive by achieving a more reliable and faster working environment, higher quality and a more efficient production and service process. Companies that integrate Industry 4.0 applications into their systems will not only gain superiority, but also achieve sustainable success by gaining a significant time and cost advantage.

This study was discussed as an evaluation of online shopping sites, which have recently become an increasingly important part of our lives. The originality of this study lies in the combination of spherical fuzzy sets with simple additive weighting in a new and challenging topic. The reason why the topic is labelled challenging is that it contains human factor and it is difficult to take this into account in the solution process. In addition, the fact that the content of the study is based on Industry 4.0 leads to difficulties in obtaining data and transferring it to the solution.

1.1 Objectives

The aim of the study was to rank some online shopping sites in Türkiye that use Industry 4.0 applications by evaluating in a fuzzy environment the aspects that online shopping sites should consider in order to achieve sustainable success. Because the range of products on offer and their selection by consumers is becoming increasingly difficult. And online shopping is beneficial to consumers who want to quickly access the products. Then the problem of selecting purchased products is therefore becoming a multi-criteria problem (Kizielewicz et al., 2022).

A fuzzy environment was chosen because the problem includes the human factor. Therefore, a fuzzy-based decision making approach was preferred for the solution, which provides more flexible and reliable results than classical decision making approaches. It was also found that online shopping sites that use Industry 4.0 applications with the obtained solution achieve better results in the selection process.

2. Literature Review

First, a literature review was conducted in which the concepts of online shopping with fuzzy sets were examined together. Rekik (2021) proposed an approach based on Fuzzy Analytic Network Process and Fuzzy Technique for Order Performance by Similarity to the Ideal Solution to rank and evaluate e-commerce websites. The proposed approach is applied to a set of shopping websites to identify their strengths and weaknesses. Tham and Nguyen (2021) proposed a methodology to evaluate the competitive advantage of online shopping websites as a case study in Vietnam. They used the Fuzzy Analytic Hierarchy Process method for weighting the criteria. Then, the fuzzy technique for preference ordering by similarity to the ideal solution is used to evaluate and rank four websites.

Revathi and Valliathal (2023) used symmetric hendecagonal fuzzy number to evaluate the websites within the Simple additive weighting procedure. They presented a ranking system based on the Centroid method, extended to symmetric hendecagonal fuzzy number, and implemented it on the websites. Sıcakyüz and Erdebilli (2023) wanted to identify the most popular online shopping sites in Turkey using an extended intuitionistic fuzzy ORESTE (Organisation, Rangement Et Synthèse De Données Relationnelles) approach. The study aimed to do this by interviewing female users of four online shopping platforms using intuitionistic fuzzy ORESTE.

Rani and Kumar (2023) discussed tangent distance measures for intuitionistic fuzzy sets and their properties. They proposed a conversion formula from real data to intuitionistic fuzzy sets data and explored a new method of MCDM with the introduction of a performance index called degree of confidence. A real-world application in the field of online shopping websites is presented to demonstrate the potential use of the proposed method. Taşdemir et al. (2023) ranked e-commerce websites in Turkey using a hybrid application of the Pythagorean Fuzzy Analytical Hierarchy Process and the Pythagorean Fuzzy Technique for Order Performance by Similarity to the Ideal Solution method. In their study, Durmaz and Aksakal (2023) used the DEMATEL method to determine the criteria to be considered when selecting online shopping sites based on Industry 4.0.

The literature review was conducted in which the concepts of online shopping and Industry 4.0 were examined together. Zamzuri et al. (2018) dealt with the impact of the Industry 4.0 revolution on the business network, including online shopping, and examined entertainment gratification, informative gratification, web irritation and self-efficacy as motivational factors in their study. Singh et al. (2021) found in their studies that with the advent of Industry 4.0, modern technologies were applied to supply chain management and the use of the Internet of Things and artificial intelligence made the online shopping experience much better and more user-friendly.

Muslikhin et al. (2021) proposed an automated picking system based on the Artificial Intelligence of Things, taking into account speed and convenience, the two fundamental points of Industry 4.0 and Society 5.0, for the development of an online shopping and services for automated shipping systems.

Borkar and Thakur (2021) explained that Industry 4.0 is developing in parallel with the rapid developments in IoT and online shopping companies are using the cloud and various data storage strategies to analyze which product will be in higher demand. Sharma et al. (2022) demonstrated the benefits of augmented reality in various areas such as online shopping by sharing information about Industry 4.0 and augmented reality.

The literature research was continued with the literature research on spherical fuzzy sets. Spherical fuzzy sets were defined by Kutlu Gündoğdu and Kahraman as an extension of intuitive fuzzy sets (2019a). Gündoğdu and Kahraman (2019b) demonstrated the applicability and validity of the classical VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method by extending it to the spherical fuzzy VIKOR method in their study on the selection of a warehouse location with four alternatives and four criteria.

In their study, Gündoğdu and Kahraman (2020) extended the classical Analytic Hierarchy Process (AHP) to the spherical fuzzy AHP (SF-AHP) method and demonstrated its applicability and validity using the example of site selection for renewable energies, as well as conducting a comparative analysis between neutrosophic AHP and SF-AHP. Gündoğdu and Kahraman (2021) have presented the score and precision functions of single-valued spherical fuzzy sets and interval-valued spherical fuzzy sets in the book chapter.

Finally, studies on the Spherical Fuzzy Simple Additive Weighting Method are included in our literature section. In the book chapter, Gündoğdu and Yörükoğlu (2021) applied Simple Additive Weighting (SAW) and Weighted Product Methods (WPM) together with spherical fuzzy sets in the selection of insurance options. Gündoğdu (2021) evaluated waste disposal technologies in the healthcare sector using the Spherical Fuzzy Simple Additive Weighting Method and the Spherical Fuzzy Weighted Multiplication Model Method.

3. Methods

In our study, we have used an approach that provides the combined use of spherical fuzzy numbers and the SAW method. A problem solving process using the SAW method can determine the weight of each criteria and then proceed with a ranking to select the best alternative (İbrahim and Surya 2019). We will talk about spherical fuzzy numbers and then show how to use them together with the SAW method, demonstrating all the steps.

3.1 Spherical fuzzy sets

Spherical fuzzy sets (SFS) were proposed by Gündoğdu and Kahraman as an extension of intuitive fuzzy sets (Gündoğdu and Kahraman 2019a). In spherical fuzzy set theory, decision makers define a membership function on a spherical surface to generalize other existing fuzzy set theories and to ensure that these membership function values are effective in a larger domain (Gündoğdu and Kahraman 2020).

SFS's are a synthesis of intuitionistic, Pythagorean and neutrosophic fuzzy sets and are characterized by a membership, a non-membership and a degree of hesitation that satisfies the condition that their sum of squares is equal to or less than one. The idea behind SFS is to allow decision-makers to generalize other extensions of fuzzy sets by defining a membership function on a spherical surface and independently assigning the parameters of this membership function to a larger space. With these properties, it provides a wider choice for decision makers in the 3D domain. An SFS must fulfill the following conditions (Gündoğdu and Kahraman 2021).

Where U is the universe of the discourse, for each u, the numbers $\mu_{\tilde{A}_s}(u)$, $v_{\tilde{A}_S}(u)$ and $\pi_{\tilde{A}_s}(u)$ are the degree of membership, non-membership and hesitancy of u to $\tilde{A}_s$, respectively. In SFS's, the sum of squares of the membership, non-membership and hesitancy parameters can be between 0 and 1, or each can be defined independently between 0 and 1 (Gündoğdu and Kahraman 2019c).

$$\tilde{A}_s = \left\{ \left(u, \left(\mu_{\tilde{A}_s}(u), v_{\tilde{A}_S}(u), \pi_{\tilde{A}_s}(u) \right) \mid u \in U \right\} \tag{1}$$

where

$$\mu_{\tilde{A}_S}(u): U \rightarrow [0,1], v_{\tilde{A}_S}(u): U \rightarrow [0,1], \pi_{\tilde{A}_S}(u): U \rightarrow [0,1]$$

and

$$0 \leq \mu_{\tilde{A}_S}^2(u) + v_{\tilde{A}_S}^2(u) + \pi_{\tilde{A}_S}^2(u) \leq 1 \quad \forall u \in U \tag{2}$$

Some basic operators for Spherical fuzzy sets that we use are as follows.

Addition;

$$\tilde{A}_S \oplus \tilde{B}_S = \left\{ \begin{array}{c} \left(\mu_{\tilde{A}_S}^2 + \mu_{\tilde{B}_S}^2 - \mu_{\tilde{A}_S}^2 \mu_{\tilde{B}_S}^2\right)^{\frac{1}{2}}, v_{\tilde{A}_S} v_{B_S}, \\ \left(\left(1 - \mu_{\tilde{B}_S}^2\right)\pi_{\tilde{A}_S}^2 + \left(1 - \mu_{\tilde{A}_S}^2\right)\pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2 \pi_{\tilde{B}_S}^2\right)^{\frac{1}{2}} \end{array} \right\} \tag{3}$$

Multiplication;

$$\tilde{A}_S \otimes \tilde{B}_S = \left\{ \begin{array}{c} \mu_{\tilde{A}_S} \mu_{\tilde{B}_S} \left(v_{\tilde{A}_S}^2 + v_{\tilde{B}_S}^2 - v_{\tilde{A}_S}^2 v_{\tilde{B}_S}^2\right)^{\frac{1}{2}}, \\ \left(\left(1 - v_{\tilde{B}_S}^2\right)\pi_{\tilde{A}_S}^2 + \left(1 - v_{\tilde{A}_S}^2\right)\pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2 \pi_{\tilde{B}_S}^2\right)^{\frac{1}{2}} \end{array} \right\} \tag{4}$$

Multiplication by a scalar; λ > 0;

$$\lambda . \tilde{A}_S = \left\{ \begin{array}{c} \left(1 - \left(1 - \mu_{\tilde{A}_S}^2\right)^{\lambda}\right)^{\frac{1}{2}}, v_{\tilde{A}_S}^{\lambda}, \\ \left(\left(1 - \mu_{\tilde{A}_S}^2\right)^{\lambda} - \left(1 - \mu_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2\right)^{\lambda}\right)^{\frac{1}{2}} \end{array} \right\} \tag{5}$$

Power of $\tilde{A}_S$; λ > 0;

$$\tilde{A}_S{}^{\lambda} = \left\{ \begin{array}{c} \mu_{\tilde{A}_S}^{\lambda} \left(1 - \left(1 - v_{\tilde{A}_S}^2\right)^{\lambda}\right)^{\frac{1}{2}}, \\ \left(\left(1 - v_{\tilde{A}_S}^2\right)^{\lambda} - \left(1 - v_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2\right)^{\lambda}\right)^{\frac{1}{2}} \end{array} \right\} \tag{6}$$

In the spherical fuzzy method with SAW, we can achieve solutions with two different average values, Spherical Weighted Arithmetic Mean (SWAM) and Spherical Weighted Geometric Mean (SWGM).

SWAM with respect to, $w = (w_1, w_2, \dots, w_n)$; $w_i \in [0,1]$ ve $\sum_{i=1}^{n} w_i = 1$, defined as,

$$SWAM_w\left(A_{S_1}, \dots, A_{S_n}\right) = w_1 A_{S_1} + w_2 A_{S_2} + \dots + w_n A_{S_n}$$

$$= \left\{ \begin{array}{c} \left[1 - \prod_{i=1}^{n} \left(1 - \mu_{\tilde{A}_{S_l}}^2\right)^{w_i}\right]^{\frac{1}{2}}, \\ \prod_{i=1}^{n} v_{A_{Si}}^{w_i}, \left[\prod_{i=1}^{n} \left(1 - \mu_{A_{Si}}^2\right)^{w_i} - \prod_{i=1}^{n} \left(1 - \mu_{A_{Si}}^2 - \pi_{A_{S_i}}^2\right)^{w_i}\right]^{\frac{1}{2}} \end{array} \right\} \tag{7}$$

SWGM with respect to, $= (w_1, w_2, \dots, w_n);\ w_i \in [0,1]$ ve $\sum_{i=1}^{n} w_i = 1$, defined as,

$$SWGM_w(\widetilde{A_{S1}}, \dots, \widetilde{A_{Sn}}) = \widetilde{A_{S1}}^{w_1} + \widetilde{A_{S2}}^{w_2} + \dots + \widetilde{A_{Sn}}^{w_n}$$
$$= \left\{ \prod_{i=1}^{n} \mu_{\widetilde{A_{Si}}}^{w_j}, \left[1 - \prod_{i=1}^{n} \left(1 - v_{\widetilde{A_{Si}}}^2\right)^{w_j}\right]^{\frac{1}{2}}, \right. \tag{8}$$
$$\left. \left[\prod_{i=1}^{n} \left(1 - v_{\widetilde{A_{Si}}}^2\right)^{w_j} - \prod_{i=1}^{n} \left(1 - v_{\widetilde{A_{Si}}}^2 - \pi_{\widetilde{A_{Si}}}^2\right)^{w_j}\right]^{\frac{1}{2}} \right\}$$

The Score and Accuracy functions are used to determine the ranking of the alternatives. Score functions and Accuracy function of sorting SFS are defined by;

Score

$$Score\left(\tilde{A}_s\right) = \left(3\mu_{\tilde{A}_s} - \frac{\pi_{\tilde{A}_s}}{2}\right)^2 - \left(\vartheta_{\tilde{A}_s} - \frac{\pi_{\tilde{A}_s}}{2}\right)^2 \tag{9}$$

Accuracy

$$Accuracy\left(\tilde{A}_s\right) = \mu_{\tilde{\lambda}_S}^2 + v_{\tilde{\lambda}_S}^2 + \pi_{\tilde{\lambda}_S}^2 \tag{10}$$

Note that: $\tilde{A}_s < \tilde{B}_s$ if and only if

i. $Score\left(\tilde{A}_s\right) < Score\left(\tilde{B}_s\right)$ *or*
ii. $Score\left(\tilde{A}_s\right) = Score\left(\tilde{B}_s\right)$ *and* $Accuracy\left(\tilde{A}_s\right) < Accuracy\left(\tilde{B}_s\right)$ (11)

3.2 Simple Additive Weighting Using Single-Valued Spherical Fuzzy Sets

The SAW method is a simple approach that is widely used in decision-making processes. Its simple structure has contributed to its popularity among users. This method is based on calculating the weighted average for each criteria in the decision matrix and also allows for the ranking of alternatives. In recent years, the SAW method has begun to demonstrate its versatility and adaptability by being applied to the fuzzy environment (Hosseinzadeh et al.2023).

Scoring methods are one of the most commonly used multi-criteria decision methods due to their simplicity and effectiveness. In our study, we use SAW, which has been extended to a fuzzy version by using single-valued spherical fuzzy sets.

The multi-criteria decision problem can be expressed as a decision matrix that displays the evaluation values of all alternatives for each criteria in a spherical fuzzy environment. Let $A_i = \{A_1, A_2, \dots, A_m\}$ $(m \geq 2)$ be a discrete set of m feasible alternatives and $C_j = \{C_1, C_2, \dots, C_n\}$ be a finite set of criteria and $w_k = \{w_1, w_2, \dots, w_s\}$ be the weight vector of all criteria which satisfies $0 \leq w_k \leq 1$ and $\sum_{k=1}^{s} w_k = 1$. The steps of the Spherical Fuzzy Simple Additive Weighting Method are as follows (Kutlu Gündoğdu 2021).

Step1. Evaluation and conversion of alternative evaluations into spherical fuzzy numbers

Using the linguistic scale of expression shown in Table 1(Kutlu Gündoğdu and Kahraman 2019), the alternatives are evaluated by the decision-makers according to criteria and decision matrices are drawn up. The resulting decision matrices are converted into spherical fuzzy numbers with the help of Table 1. For example, the term (AMI) is replaced by the spherical fuzzy number (0.9, 0.1, 0.1) .

Table 1. Linguistic terms

Linguistic terms	$(\mu; \nu; \pi)$
Absolutely more importance (AMI)	(0.9, 0.1, 0.1)
Very high importance (VHI)	(0.8, 0.2, 0.2)
High importance (HI)	(0.7, 0.3, 0.3)
Slightly more importance (SMI)	(0.6, 0.4, 0.4)
Equally importance (EI)	(0.5, 0.5, 0.5)
Slightly low importance (SLI)	(0.4, 0.6, 0.4)
Low importance (LI)	(0.3, 0.7, 0.3)
Very low importance (VLI)	(0.2, 0.8, 0.2)
Absolutely low importance (ALI)	(0.1, 0.9, 0.1)

Step 2: Determination of the aggregated spherical fuzzy decision matrices of the alternatives
The decision matrices are converted into an aggregated spherical fuzzy decision matrix using the spherically weighted geometric mean operator (Eq.8). The structure of the stacked decision matrix is shown in Eq.12.

$$\tilde{a}_{ij} = \left(C_j(\tilde{a}_i)\right)_{mxn} = \begin{bmatrix} (\mu_{11}; \nu_{11}; \pi_{11}) & \dots & (\mu_{1n}; \nu_{1n}; \pi_{1n}) \\ (\mu_{21}; \nu_{21}; \pi_{21}) & \dots & (\mu_{2n}; \nu_{2n}; \pi_{2n}) \\ \dots & \dots & \dots \\ (\mu_{m1}; \nu_{m1}; \pi_{m1}) & \dots & (\mu_{mn}; \nu_{mn}; \pi_{mn}) \end{bmatrix} \quad (12)$$

Step 3: Evaluation and conversion of the criteria ratings into spherical fuzzy numbers
Using the linguistic expression scale in Table 1, the decision makers create matrices to evaluate the importance of the criteria in relation to each other. The resulting matrices are converted into spherical fuzzy numbers with the help of Table 1.

Step 4: Determining the aggregated importance levels of the criteria
The matrices for evaluating the criteria are converted into a matrix for the aggregated importance of the criteria using the SWGM operator given in Eq.8.

Step 5: Determination of the score values and the normalized values of the aggregated criteria
The score values of the aggregated criteria obtained are with using Eq.13. The values found are then normalized using Eq.14.

$$S(\widetilde{w}_j) = \left(3\mu_j - \frac{\pi_j}{2}\right)^2 - \left(\nu_j - \frac{\pi_j}{2}\right)^2 \quad (13)$$

$$\widetilde{w}_j = \frac{S(\widetilde{w}_j)}{\sum_{j=1}^{n} S(\widetilde{w}_j)} \quad (14)$$

Step 6: Multiplication of the aggregated decision matrix with the criteria weights
First, the criteria weights and the aggregated decision matrix are multiplied using Eq. 15 and then the fuzzy products are summed.

$$\tilde{A}_i = \sum_{j=1}^{n} \widetilde{w}_j \tilde{a}_{ij} \quad (15)$$

Step 7: Refining the $\tilde{A}_i$ values
The $\widetilde{A}_i$ values are clarified with the help of Eq.16. Then the alternatives are classified according to their defuzzified a_i values.

$$a_i = Score(\tilde{A}_i) = \left(3\mu_{\tilde{A}_i} - \frac{\pi_{\tilde{A}_i}}{2}\right)^2 - \left(\vartheta_{\tilde{A}_i} - \frac{\pi_{\tilde{A}_i}}{2}\right)^2 \quad (16)$$

4. Data Collection

In our study, 3 expert E_i (decision makers) opinions were taken into account to solve the problem. Experts are professionals working in the field of online shopping. First expert has 10 years, second expert 8 years and third expert 6 years of working experience in the the field of online shopping industry. The criteria C_i to be considered in the study include customer expectations when online shopping, starting with the research to obtain information about the product, through to the purchase and delivery of the product. Meeting these expectations creates satisfaction and loyalty among customers and contributes to the site being preferred again when online shopping. The five alternatives A_i were selected from sites that use Industry 4.0 applications and are preferred by people. Information including the criteria and their explanations are given in Table 2.

Table 2. Criteria that are effective in the selection of online shopping sites

Criteria	Description
Product information and variety	All necessary information about the product or service must be provided. The greater the variety of products, the more consumers will be aware of them.
Correct and punctual delivery	The order must be delivered complete, undamaged and within the promised time.
Website design and performance	The website should attract the consumer's attention and be simple and easy to understand.
Reliability/confidentiality	All precautions should be taken to protect customer data and all information should be protected against cyber-attacks on the website.
Customer satisfaction	Customer requests and needs should be responded to quickly and attention should be paid to customer service.

5. Results and Discussion

In the study, the weights of the criteria are determined first. The 3 expert determined the Spherical fuzzy linguistic expression for each alternatives through criteria. The criteria weights are determined using the procedures described, including step 5 in the Method section. After determining the criteria weights, the ranking of the alternatives is determined in steps 6 and 7.

Step 1: Matrices are created in which the alternatives $(A_i)$are evaluated according to the criteria (C_i) defined by each expert (E_i). The opinions of each experts are listed in Table 3 with linguistic terms.

Table 3. Spherical fuzzy linguistic expression decision matrices

		C_1	C_2	C_3	C_4	C_5
(E_1)	A_1	HI	HI	AMI	LI	AMI
	A_2	AMI	HI	HI	EI	AMI
	A_3	HI	HI	HI	ALI	HI
	A_4	HI	AMI	AMI	LI	AMI
	A_5	HI	AMI	HI	HI	HI
(E_2)	A_1	HI	HI	AMI	AMI	AMI
	A_2	HI	HI	AMI	HI	AMI
	A_3	EI	HI	HI	EI	AMI
	A_4	LI	EI	HI	ALI	HI
	A_5	ALI	LI	HI	LI	HI
(E_3)	A_1	AMI	HI	AMI	AMI	AMI
	A_2	HI	AMI	HI	HI	AMI
	A_3	HI	AMI	AMI	EI	HI
	A_4	EI	HI	EI	LI	HI
	A_5	LI	LI	HI	EI	HI

Step 2: The values declared in Table 3 are then transformed with the equivalents according to Table 1 and converted into an aggregated spherical fuzzy decision matrix using Eq.8. The weights of the decision makers were taken as the same.Then Table 4, aggregated spherical fuzzy decision matrix of the alternatives is obtained.

Table 4. Aggregated decision matrix

	$C_1\ (\mu;\nu;\pi)$	$C_2\ (\mu;\nu;\pi)$	$C_3(\mu;\nu;\pi)$	$C_4(\mu;\nu;\pi)$	$C_5(\mu;\nu;\pi)$
A_1	(0.761, 0.253, 0.256)	(0.761, 0.253, 0.256)	(0.900, 0.100, 0.100)	(0.624, 0.454, 0.234)	(0.900, 0.100, 0.100)
A_2	(0.761, 0.253, 0.256)	(0.828, 0.193, 0.198)	(0.761, 0.253, 0.256)	(0.626, 0.383, 0.397)	(0.900, 0.100, 0.100)
A_3	(0.626, 0.383, 0.397)	(0.828, 0.193, 0.198)	(0.761, 0.253, 0.256)	(0.292, 0.725, 0.345)	(0.761, 0.253, 0.256)
A_4	(0.472, 0.545, 0.384)	(0.680, 0.350, 0.374)	(0.680, 0.350, 0.374)	(0.208, 0.796, 0.224)	(0.761, 0.253, 0.256)
A_5	(0.276, 0.745, 0.222)	(0.433, 0.603, 0.281)	(0.700, 0.300, 0.300)	(0.472, 0.545, 0.384)	(0.700, 0.300, 0.300)

For the calculation: (0.761, 0.252, 0.256)

$$0{,}761 = 0{,}70^{0{,}333} * 0{,}70^{0{,}333} * 0{,}90^{0{,}333}$$

$$0{,}253 = \sqrt{1 - ((1-0{,}3^2)^{0{,}333} * (1-0{,}3^2)^{0{,}333} * (1-0{,}1^2)^{0{,}333})}$$

$$0{,}256 = \sqrt{((1-0{,}3^2)^{0{,}333} * (1-0{,}3^2)^{0{,}333} * (1-0{,}1^2)^{0{,}333}) - ((1-0{,}3^2-0{,}3^2)^{0{,}333} * (1-0{,}3^2-0{,}3^2)^{0{,}333} * (1-0{,}1^2-0{,}1^2)^{0{,}333})}$$

Step 3: With the use of the decision makers opinion, a matrix Table 5 created to evaluate the importance of the criteria concerning each other with using the linguistic expression scale in Table 1.

Table 5. Spherical fuzzy linguistic expression of criteria importance levels

	$C_1\ (\mu;\nu;\pi)$	$C_2\ (\mu;\nu;\pi)$	$C_3(\mu;\nu;\pi)$	$C_4(\mu;\nu;\pi)$	$C_5(\mu;\nu;\pi)$
E_1	EI	EI	HI	LI	LI
E_2	EI	AMI	AMI	HI	AMI
E_3	EI	HI	AMI	HI	HI

Step 4: The matrix for evaluating the criteria imprtance levels converted into a matrix for the aggregated importance of the criteria using the SWGM operator given in Eq 8. Then the final values for each criteria obtained in Table 6.

Table 6. Aggregated importance levels of the criteria

$C_1\ (\mu;\nu;\pi)$	$C_2\ (\mu;\nu;\pi)$	$C_3(\mu;\nu;\pi)$	$C_4(\mu;\nu;\pi)$	$C_5(\mu;\nu;\pi)$
(0.5, 0.5, 0.5)	(0.68, 0.35, 0.374)	(0.624, 0.454, 0.234)	(0.528, 0.50, 0.307)	(0.574, 0.478, 0.275)

For the calculation: (0.5, 0.5, 0.5)

$$0{,}5 = 0{,}50^{0{,}333} * 0{,}50^{0{,}333} * 0{,}50^{0{,}333}$$

$$0{,}5 = \sqrt{1 - ((1-0{,}5^2)^{0{,}333} * (1-0{,}5^2)^{0{,}333} * (1-0{,}5^2)^{0{,}333})}$$

$$0{,}5 = \sqrt{((1-0{,}5^2)^{0{,}333} * (1-0{,}5^2)^{0{,}333} * (1-0{,}5^2)^{0{,}333}) - ((1-0{,}5^2-0{,}5^2)^{0{,}333} * (1-0{,}5^2-0{,}5^2)^{0{,}333} * (1-0{,}5^2-0{,}5^2)^{0{,}333})}$$

Step 5:

The score values of the aggregated criteria $S(\tilde{w}_j)$ were obtained by using Eq.13. The values found are then normalized using Eq. 14 and found as criteria weights $(\tilde{w}_j)$. According to the calculations, correct and punctual delivery ranked as the first and most important criteria.

Table 7. Score values and the normalized values of the aggregated criteria

	$S(\widetilde{w}_j)$	$(\widetilde{w}_j)$	Criteria Rank
C_1	1,50	0,123	5
C_2	3,412	0,280	1
C_3	2,967	0,243	2
C_4	1,925	0,158	4
C_5	2,394	0,196	3

$$S(\widetilde{w}_1) = 1{,}50 = ((3 * 0{,}5) - (\frac{0{,}5}{2}))^2 - (0{,}5 - (\frac{0{,}5}{2}))^2$$

$$Total\ S(\widetilde{w}_1) = 12{,}197$$

$$(\widetilde{w}_j) = \frac{1{,}50}{12{,}197} = 0{,}123$$

Step 6: The criteria weights (Table 7, $\widetilde{w}_j$ values) and the aggregated decision matrix (Table 4) values are multiplied by using Eq. 15.

Table 8. Multiplication of the aggregated decision matrix with the criteria weights

	$C_1\ (\mu;\nu;\pi)$	$C_2\ (\mu;\nu;\pi)$	$C_3(\mu;\nu;\pi)$	$C_4(\mu;\nu;\pi)$	$C_5(\mu;\nu;\pi)$
A_1	(0.318, 0.845, 0.136)	(0.464, 0.681, 0.191)	(0.576, 0.571, 0.093)	(0.274, 0.883, 0.117)	(0.527, 0.636, 0.087)
A_2	(0.318, 0.845, 0.136)	(0.526, 0.632, 0.162)	(0.436, 0.716, 0.181)	(0.275, 0.860, 0.207)	(0.527, 0.636, 0.087)
A_3	(0.243, 0.889, 0.185)	(0.526, 0.632, 0.162)	(0.436, 0.716, 0.181)	(0.118, 0.950, 0.146)	(0.395, 0.764, 0.166)
A_4	(0.175, 0.928, 0.157)	(0.400, 0.746, 0.261)	(0.375, 0.775, 0.246)	(0.083, 0.965, 0.092)	(0.395, 0.764, 0.166)
A_5	(0.098, 0.964, 0.082)	(0.237, 0.868, 0.163)	(0.389, 0.746, 0.198)	(0.197, 0.909, 0.177)	(0.352, 0.790, 0.181)

For the calculation: (0.318, 0.845, 0.136)

$$0{,}318 = \sqrt{1 - ((1 - 0{,}76^2)^{0{,}123}})$$

$$0{,}845 = 0{,}25^{0{,}123}$$

$$0{,}136 = \sqrt{(1 - 0{,}76^2)^{0{,}123} - (1 - 0{,}76^2 - 0{,}26^2)^{0{,}123}})$$

Step 7: After finding the spherical fuzzy values (Table 8) the summation process is performed. The $(\mu;\nu;\pi)$values are found out with Eq. 15 which was derived with the help of Eq. 3, and the multiplication operation was derived with the help of Eq. 5. The scalar value in Eq.5 is taken as 1/criteria number that is, 0.2.

The score values are clarified with the help of Eq. 16. The alternative with the highest score is determined as the best alternative. As seen in Table 9, in our solution the best alternative is obtained as the first alternative.

Table 9. Score values and ranks

	$(\mu;\nu;\pi)$	$Score$	Alternative Rank
A_1	(0.414, 0.759, 0.137)	0,904	1
A_2	(0.402, 0.761, 0.173)	0,799	2
A_3	(0.304, 0.835, 0.186)	0,120	3
A_4	(0.243, 0.874, 0.177)	-0,204	4
A_5	(0.229, 0.883, 0.156)	-0,278	5

For the calculation: (0.414, 0.759, 0.137)

$$0{,}414 = 0{,}318^{0{,}2} * 0{,}464^{0{,}2} * 0{,}576^{0{,}2} * 0{,}274^{0{,}2} * 0{,}527^{0{,}2}$$

$$0{,}759 = \sqrt{1 - ((1-0{,}845^2)^{0{,}2} * (1-0{,}681^2)^{0{,}2} * (1-0{,}571^2)^{0{,}2} * (1-0{,}883^2)^{0{,}2} * (1-0{,}636^2)^{0{,}2})}$$

$$0{,}137 = \sqrt{\begin{array}{c}((1-0{,}845^2)^{0{,}2} * (1-0{,}681^2)^{0{,}2} * (1-0{,}571^2)^{0{,}2} * (1-0{,}883^2)^{0{,}2} * (1-0{,}636^2)^{0{,}2}) - \\ ((1-0{,}845^2-0{,}136^2)^{0{,}2} * (1-0{,}681^2-0{,}191^2)^{0{,}2} * (1-0{,}571^2-0{,}0{,}093^2)^{0{,}2}) * \\ (1-0{,}883^2-0{,}117^2)^{0{,}2} * (1-0{,}636^2-0{,}087^2)^{0{,}2})\end{array}}$$

$$Score\ A_1 = 0{,}904 = ((3 * 0{,}414) - (\frac{0{,}137}{2}))^2 - (0{,}759 - (\frac{0{,}137}{2}))^2$$

According to the results obtained, the solution based on the criteria and alternatives considered by the experts was obtained in a way that reflects the real situation. The most popular shopping website also ranks first in the ranking.

6. Conclusion

In this study, we proposed a methodology for the selection of online shopping websites based on customer preferences. During the evaluation process, the criteria that affect consumers' online shopping preferences were identified among the websites that use Industry 4.0 applications. Again, some of the websites using Industry 4.0 were included as alternatives in the evaluation process. All these processes were conducted in a fuzzy environment. The reason for using fuzzy is that there is a human factor in the selection process and the concept of Industry 4.0 is more effectively integrated into the problem. The results obtained with the applied method showed that the result obtained by solving the problem was consistent with the results obtained in practice. This shows that the problem was correctly adapted and reflects the situation.

In our study, we used SAW's SWGM averaging method. In future studies, the analysis can be performed with the arithmetic mean operator, and an approach that compares the results of both operators can also be used. In addition, the analysis can be performed using other multi-criteria decision making methods, including those mentioned in the literature and in our study. It is also possible to achieve different and better results depending on the area of application, based on different criteria and alternatives. In this context, the study also has the potential to be integrated into new problems and bring benefits.

References

Borkar, P. S., and Thakur, R., Smart Environment Monitoring Models Using Cloud-Based Data Analytics: A Comprehensive Study, *Machine Learning Approach for Cloud Data Analytics in IoT*, 227-271. 2021.

Buster, J., E-commerce, https://www.wto.org/e_com_e_lib/en/JargonBuster/. Accessed May 10, 2024

Cavlak, E. Onlıne alışveriş sitesi tercihinde etkili olan kriterlerin belirlenmesine ve önceliklendirilmesine yönelik bir karar modeli (Doctoral dissertation, Fen Bilimleri Enstitüsü), 2012. (In Turkish)

Desticioglu T., B., Kumcu, S., & Ozyoruk, B., Comparison of E-Commerce Sites with Pythagorean Fuzzy AHP and TOPSIS Methods. In *International Conference on Intelligent and Fuzzy Systems* pp. 327-335, Cham: Springer Nature Switzerland, August, 2023.

Durmaz, Z., and Aksakal, E., Endüstri 4.0 Temelinde Online Alişveriş Sitelerinin Seçiminde Dikkate Alinacak Kriterlerin DEMATELYöntemi ile Değerlendirilmesi. *Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi*, *26(Özel Sayı),* 1147-1155, 2023. (In Turkish)

Evans, P. C., and Annunziata, M., Industrial internet: Pushing the boundaries. *General Electric Reports*, 488-508, 2012.

Gündoğdu, F. K., and Kahraman, C. A novel fuzzy TOPSIS method using emerging interval-valued spherical fuzzy sets, *Engineering Applications of Artificial Intelligence*, 85, 307-323,2019c.

Gündoğdu, F. K., and Kahraman, C., Properties and Arithmetic Operations of Spherical Fuzzy Sets, In: Kahraman, C., Kutlu Gündoğdu, F. (eds) *Decision Making with Spherical Fuzzy Sets. Studies in Fuzziness and Soft Computing*, vol 392. Springer, Cham, 2021.

Gündoğdu, F.K., and Kahraman, C. A novel VIKOR method using spherical fuzzy sets and its application to warehouse site selection, *Journal of Intelligent & Fuzzy Systems*, vol. 37, no. 1, pp. 1197-1211, 2019b.

Gündoğdu, F.K., and Kahraman, C., A novel spherical fuzzy analytic hierarchy process and its renewable energy application, *Soft Computing*, vol. 24, no. 1, pp. 4607-4621, 2020.

Gündoğdu, F.K., and Kahraman, C., Spherical fuzzy sets and spherical fuzzy TOPSIS method, *Journal of intelligent & fuzzy systems*, vol. 36, no. 1, pp. 337-352, 2019a.
Gündoğdu, F.K., and Yörükoğlu, M. Simple additive weighting and weighted product methods using spherical fuzzy sets, In: Kahraman, C., Kutlu Gündoğdu, F. (eds) *Decision Making with Spherical Fuzzy Sets. Studies in Fuzziness and Soft Computing*, vol 392. Springer, Cham, 2021.
Gündoğdu, F.K., Küresel Bulanık Basit Toplamlı Ağırlıklandırma Yöntemi ve Ağırlıklandırılmış Çarpım Modeli ile Sağlık Sistemindeki Atık İmha Teknolojilerinin Değerlendirilmesi. *Bulanık Çok kriterli karar verme yöntemleri MS Excel ve Software Çözümlü Uygulamalar*, Ankara, 411-417. 2021.
Hosseinzadeh Lotfi, F., Allahviranloo, T., Pedrycz, W., Shahriari, M., Sharafi, H., Razipour GhalehJough, S., Simple Additive Weighting (SAW) Method in Fuzzy Environment, *In: Fuzzy Decision Analysis: Multi Attribute Decision Making Approach. Studies in Computational Intelligence*, vol 1121. Springer, Cham. 2023.
Ibrahim, A., & Surya, R. A., The implementation of simple additive weighting (SAW) method in decision support system for the best school selection in Jambi, *In Journal of Physics: Conference Series*, vol. 1338, no. 1, pp. 012054. IOP Publishing, 2019.
Kizielewicz, B., Bączkiewicz, A., Shekhovtsov, A., Więckowski, J., Sałabun, W., Can MCDA Methods Be Useful in E-commerce Systems? Comparative Study Case, In: Woungang, I., Dhurandher, S.K., Pattanaik, K.K., Verma, A., Verma, P. (eds) *Advanced Network Technologies and Intelligent Computing*. 2022.
May 10, 2024.
Muslikhin, M., Horng, J. R., Yang, S. Y., Wang, M. S., and Awaluddin, B. A., An artificial intelligence of things-based picking algorithm for online shop in the society 5.0's context, *Sensors*, vol. 21, no. 8, pp., 2813. 2021.
OECD, https://www.oecd-ilibrary.org/science-and-technology/unpacking-e-commerce_23561431-en/, Accessed
Rani, V., and Kumar, S., MCDM Method for evaluating and ranking the online shopping websites based on a novel distance measure under intuitionistic fuzzy environment, In *Operations Research Forum*, Vol. 4, No. 4, p. 78, Cham: Springer International Publishing, 2023.
Rekik, R., An Integrated Fuzzy ANP-TOPSIS Approach to Rank and Assess E-Commerce Web Sites, In: Abraham, A., Shandilya, S., Garcia-Hernandez, L., Varela, M. (eds) *Hybrid Intelligent Systems. HIS 2019, Advances in Intelligent Systems and Computing*, vol 1179. Springer, Cham, 2021.
Revathi, M., & Valliathal, M., Website selection for online shopping by multi-criteria decision analysis using symmetric hendecagonal fuzzy number, *International Journal of Mathematics in Operational Research*, *24*(3), 339-359, 2023.
Sharma, A., Mehtab, R., Mohan, S., and Mohd Shah, M. K., Augmented reality–an important aspect of Industry 4.0, *Industrial Robot: the international journal of robotics research and application*, vol. 49, no. 3, pp. 428-441, 2022.
Sıcakyüz, Ç., and Erdebilli, B., Is E-Trust a Driver of Sustainability? An Assessment of Turkish E-Commerce Sector with an Extended Intuitionistic Fuzzy ORESTE Approach, *Sustainability*, *15*(13), 10693, 2023.
Singh, S., Gupta, A., and Shukla, A. P., Optimizing Supply Chain through Internet of Things (IoT) and Artificial Intelligence (AI), *2021 International Conference on Technological Advancements and Innovations (ICTAI)* pp. 257-263, Tashkent, Uzbekistan, November 10-12, 2021.
Tham, T. T., and Nguyen, H. P., An integrated approach of Fuzzy-AHP-TOPSIS for e-commerce evaluation, *Industrial Engineering & Management Systems*, *20*(2), 82-95, 2021.
Zamzuri, N. H., Kassim, E. S., Shahrom, M., and Humaidi, N., Entertainment gratification, informative gratification, web irritation and self-efficacy as motivational factors to online shopping intention, *Management & Accounting Review (MAR),* vol. 17, no. 3, pp. 95-108, 2018.

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