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A novel CINFUS-SWARA-TOPSIS methodology for evaluating horizontal Alliances between hotels and airlines

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ABSTRACT

This study introduces an innovative approach to strategic decision-making in the hospitality business, with a focus on selecting the best hotel option for the Hotel Airlines Alliance in Türkiye. The incorporation of SWARA (Step-Wise Weight Assessment Ratio Analysis) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) approaches within the Continuous Intuitionistic Fuzzy Sets (CINFUSs) environment is an original effort in decision-making procedures. The evaluation process involved ten hotel alternatives and considered five criteria: Scale and scope possibility, Brand value, Tourism attraction, Operating cost, and Industrial conditions. In the second stage, the subjective criterion weights obtained in the first stage were utilized to rank the 10 hotel alternatives using the CINFUS-TOPSIS approach, with the highest preference potential being prioritized in the first position. The integration of SWARA and TOPSIS facilitated a comprehensive assessment that combined expert opinions (SWARA) for determining criteria weights and mathematical modeling (TOPSIS) for ranking alternatives.

1. Introduction

The tourism industry is a dynamic sector that has become a major economic force in the modern world, contributing significantly to global economic growth and employment. This industry has a complex network that not only meets the accommodation needs of tourists but also requires integration between air transportation, accommodation, leisure, and other tourist activities. In this context, cooperation between airlines and hotels has the potential to provide better services to tourists, gain a competitive advantage, and increase the sustainability of tourism destinations. Especially in tourist destinations such as Türkiye, the interaction between these sectors has the potential to increase customer satisfaction and experience.

The concept of Hotel Airline Alliance (HAA) typically refers to a partnership or agreement between a hotel chain or individual hotels and an airline or airline alliance. This collaboration aims to provide added benefits and convenience to travelers by offering integrated services and loyalty programs. These alliances may include benefits such as discounted rates, bonus points, seamless booking processes, and coordinated marketing efforts to attract mutual customers. The specific terms and benefits of such alliances can vary widely depending on the parties involved and the details of their agreement. Airline and hotel collaboration is a critical procedure that involves complexity and uncertainty when making strategic decisions in the tourism industry. These collaborations are performed in order to improve the tourist travel experience, acquire a competitive advantage, and maximize overall customer satisfaction. However, strategic decisions, such as selecting the best hotel, contain complex and multifaceted factors that are not always apparent.

This is where fuzzy multi-criteria decision-making methods (Fuzzy MCDM) come into play. MCDM approaches used in the Crisp environment, in other words, in one-dimensional space, are mathematical approaches that aim to select the best alternative from a large number of alternatives by considering more than one criterion used in evaluating these alternatives at the same time. They are approaches that support decision-making processes, especially when the number of alternatives to choose from and the number of criteria to be considered in evaluating these alternatives increases. MCDM approaches can be categorized as those that are simply used to find criteria weights and those that are used to rank alternatives. Moreover, different analytical approaches to decision-making processes can be developed with integrated methodologies obtained with ranking approaches that use the criteria weights obtained from the methods used to find weights. After the fuzzy set theory was introduced to the literature by Zadeh (1978), researchers started to extend MCDM methods to different fuzzy sets and made them available to scholars.

In this study, an integrated methodology is proposed by extending the SWARA (Step-wise Weight Assessment

Research Paper

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Ratio Analysis) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) approaches to Continuous Intuitionistic Fuzzy Sets (CINFUS) which is introduced by Alkan and Kahraman (2023) for the first time to the best of our knowledge. This novel methodology aims to select the most appropriate hotel among 10 different hotels in Türkiye in the context of "HAA". The main motivation of this novel methodology is to help tourism industry stakeholders make more robust and knowledge-based decisions that involve uncertainty and complexity.

Partner selection in the context of HAA is a highly important decision for both hotels and airlines. For both parties, customer dissatisfaction as a result of making the wrong choice for such a collaboration can directly damage the brand image and lead to huge revenue losses. In this study, an integrated SWARA-TOPSIS methodology in the CINFUS environment is proposed for the first time in the literature in order to minimize the potential damaging consequences of partner selection in the context of HAA. The contributions of this study to the literature can be summarized as follows:

- Like many strategic decisions in everyday business life, partner selection for HAA is a decision process that is not crystal clear and inherently involves incomplete information and inconsistent situations in the decision process. With the proposed Fuzzy-MCDM methodology, decision problems with these characteristics can better reflect the nature of the process in the model.
- The SWARA method, which is used to find subjective criteria weights, allows the calculation of criteria weights in line with the opinions of decision makers (DM's). Thus, the knowledge and experience of decision makers can be included in the model. Especially in a strategic decision such as HAA partner selection, the possible negative consequences of the decisions to be made can be minimized with the help of the mathematical model obtained by including experience in the process.
- The TOPSIS approach, which is preferred for ranking alternatives, is widely preferred by researchers in the literature because it is an approach that calculates positive and negative solution sets and ranks each alternative according to their distance to these solution sets. This characteristic feature of TOPSIS, which is one of the traditional MCDM approaches used in this study in an integrated manner with the SWARA approach, increases the reliability of the results obtained.
- The extension of the integrated SWARA-TOPSIS approach to the CINFUS environment allows the mathematical model to be realized within a specific range and thus allows DMs to express their views more naturally.

With these mentioned advantages, the proposed integrated CINFUS-SWARA-TOPSIS approach aims to provide more reliable results for scholars decision-making processes. Due to the high uncertainty in the decision-making process and the scarcity of studies using Fuzzy-MCDM approaches and even the lack of studies in Turkey, the partner selection problem for HAA has been chosen as an application of the methodology proposed in this study.

2. Literature

This section summarizes the associated work in order to briefly shed light on the existing literature gap, give greater insights into the values of this research, and more explicitly highlight the work's uniqueness. For this reason, recent MCDM works employing Intuitionistic Fuzzy Sets, Continuous intuitionistic fuzzy sets, and the hotel selection problem are discussed.

Intuitionistic Fuzzy MCDM Application

Atanassov (1983) proposed intuitionistic fuzzy sets as a modified version of FSs to better deal with ambiguity in real-world applications. IFSs indicated by membership and non-membership degrees cope with data uncertainties or decision-makers' partial knowledge, but they additionally indicate decision-makers hesitations during decision-making phases. Following the introduction of IFSs, academics created novel procedures and frameworks based on IFSs, which are now widely utilized. Atanassov (1983) introduced novel operators, operations, and fundamental characteristics based on IFSs. Then, Atanassov (1983) presented an IFS-based decision-making with multiple criteria techniques including numerous persons and

Table 1: IFS-Based Studies in the Literature

Author(s)	Methodology	Decision-making problem
Chaurasiya and Jain (2021)	IF-ENTROPY & IF-MARCOS	Mobile Facility Distributor Selection
Ecer (2022)	IF-MAIRCA	Coronavirus Vaccine Selection
Rani et al. (2021)	IF-GRA	Telecom Service Provider Assessment
Badi and Pamucar (2020)	IF-Grey-MARCOS	Supplier selection
Chai et al. (2023)	IVIF-TOPSIS	Sustainable supplier selection
İlbaş et al. (2023)	IF-PR & SMAA-2	Supplier selection
Karagoz et al. (2020)	IF-CODAS	Location selection for dismantling centre
Boran et al. (2009)	IF-TOPSIS	Supplier selection
Memari et al. (2019)	IF-TOPSIS	Spare parts manufacturer selection for the automotive sector
Buran and Erçek (2022)	IF-AHP	Public transportation model evaluation
Dogan et al. (2020)	IVIF-AHP-TOPSIS	Corridor selection for locating autonomous vehicles
Ilbahar et al (2022)	IF-AHP	Risk assessment of renewable energy investment
Su, (2020)	IF-AHP	Building material supplier selection

Source: Author’s own elaboration

measuring instruments. In the period that followed, scholars made extensive use of IFS. Table 1 shows that different MCDM methods have been employed to solve many different decision problems in the IFS environment. Continuous intuitionistic fuzzy sets (CINFUSs) was introduced to the literature by Alkan and Kahraman (2023) as an extension of the traditional IFS in cautious form. Alkan and Kahraman (2023) developed an extension of AHP and TOPSIS methods in the CINFUS environment and applied it in the field of research proposals evaluation for grant funding.

Hotel selection problems

Hotel selection in the Hotel-Airline Alliance (HAA) context is often analyzed on the basis of previous experience, heuristics or assessments of airline decision-making committees (DMCs). However, heuristics are not always considered the most reliable decision-making method, as subjective assessments can be influenced by the initial perceptions and feelings of decision makers (DMs). In this process, there are several factors that decision makers (DMs) need to consider when choosing a hotel. These include hotel location, logistics, consumer expectations, transportation infrastructure, guest reception standards, hygiene conditions, food quality, and relevant government regulations (Chen et al., 2014; Fu, 2019; Roy et al., 2019). The selection of a hotel under the HAA requires the evaluation of multiple conflicting criteria, thus necessitating a multi-criteria decision-making (MCDM) process. Based on literature analysis and expert opinions, nominal group technique (NGT) is a method used to identify these criteria.

Previous research on hotel selection has often focused on certain key qualitative elements. For example, Lee et al. (2010) examined a five-star hotel chain in Seoul, South Korea and used exploratory factor analysis to identify factors such as tourist attraction, environmental factors, safety, traffic, comfort and accessibility. Similarly, Juan and Lin (2013) conducted a survey and identified hotel selection criteria as proximity to the airport, demand conditions, business strategy, equipment factors, supporting industries, government policies, and random factors. Sohrabi et al. (2012) conducted exploratory factor analysis to identify the most important hotel selection variables and evaluated guest comfort, staff service quality, hygiene, room equipment, internet access, parking facilities, costs, security and entertainment facilities.

Other studies on hotel selection processes have focused on mathematical models. For example, Benitez et al. (2007) developed a fuzzy logic approach based on the Technique for Preference Ranking by Similarity to an Ideal Solution (TOPSIS) model to reduce uncertainties arising from the subjective evaluations of decision makers in the process of dynamic monitoring of service quality. Chou et al. (2008) proposed a fuzzy FCDM model for hotel selection that includes traffic conditions, geographical variables, hotel attributes and operational management factors. Li et al. (2013) constructed a multi-criteria decision-making framework using Choquet-integral (CI) methodology to analyze tourists' accommodation preferences.

On the other hand, studies in the context of luxury vacation hotels are also noteworthy. Gil-Lafuente et al. (2014) used Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Delphi Method (FDM) techniques to identify the selection criteria of these hotels. Mardani et al. (2016) developed an integrated approach including FDM, FAHP, TOPSIS and VIKOR methodologies to evaluate quality management strategies in hotel organizations. Zolfani et al. (2017) proposed a hybrid CRM methodology including SWARA and COPRAS methodologies in the evaluation process of hotel buildings with a focus on environmental sustainability. Cheng (2018a, 2018b) developed a new Authoritarian Multi-attribute Group Decision Making (AMAGDM) technique based on interval heuristic fuzzy sets for hotel location evaluation. In this framework, considering factors such as geographical location, traffic density, hotel amenities, and operational management, decision makers' evaluation weights are modeled with interval-valued intuitionistic fuzzy values (IVIFVs). In addition, Yu et al. (2018) developed a new distance measure to analyze online hotel reviews on tourism websites and the distribution of linguistic datasets. Roy et al. (2019) applied the integrated Weighted Interval Rough Number (WIRN) approach and WIRN-based COPRAS model to analyze web-based hotel selection.

3. Preliminaries

The research in the literature demonstrates that intuitionistic fuzzy sets are among the most widely employed fuzzy sets by researchers. Researchers can define the non-membership degree as well as the membership degree using intuitionistic fuzzy sets. Developed by Alkan and Kahraman (2023), continuous intuitionistic fuzzy sets (CINFUSs) are an extension of intuitionistic fuzzy sets that define continuous membership and non-membership values for every element in an identified set, ranging from zero to one.

Continuous intuitionistic fuzzy sets (CINFUS)

Basic operations corresponding to CINFUSs are detailed below.

Definition 2.1: Let X be a non-empty set. A CINFUS, $\mathbb{C}$ in X is an object in in the form of:

$$\tilde{\mathbb{C}} = \{\langle \boldsymbol{x}, \boldsymbol{F}(\boldsymbol{\mu}_{\tilde{\mathbb{C}}}(\boldsymbol{x}), \boldsymbol{\tau}), \boldsymbol{F}(\boldsymbol{\vartheta}_{\tilde{\mathbb{C}}}(\boldsymbol{x}), \boldsymbol{\tau})\rangle \mid \boldsymbol{x} \boldsymbol{\epsilon} \boldsymbol{X}\} \quad \textbf{(1)}$$

The functions $F(\mu_{\tilde{\mathbb{C}}}(x), \tau): X \rightarrow [0,1]$ and $F(\vartheta_{\tilde{\mathbb{C}}}(x), \tau): X \rightarrow [0,1]$ represent continuous membership and non-membership degrees of x in the $\tilde{\mathbb{C}}$, respectively. Also, where $F(\mu_{\tilde{\mathbb{C}}}(x), \tau) = \alpha\tau - \alpha\tau^2$ and $\boldsymbol{R}(\vartheta_{\tilde{\mathbb{C}}}(x), \tau) = (4-\alpha)\tau - (4-\alpha)\tau^2$. A CINFUS $\tilde{\mathbb{C}}$ meets the requirement of $0 \leq F(\mu_C(x), \tau) + F(\vartheta_C(x), \tau) \leq 1 \quad = 0 \leq \alpha\tau - \alpha\tau^2 + (4-\alpha)\tau - (4-$

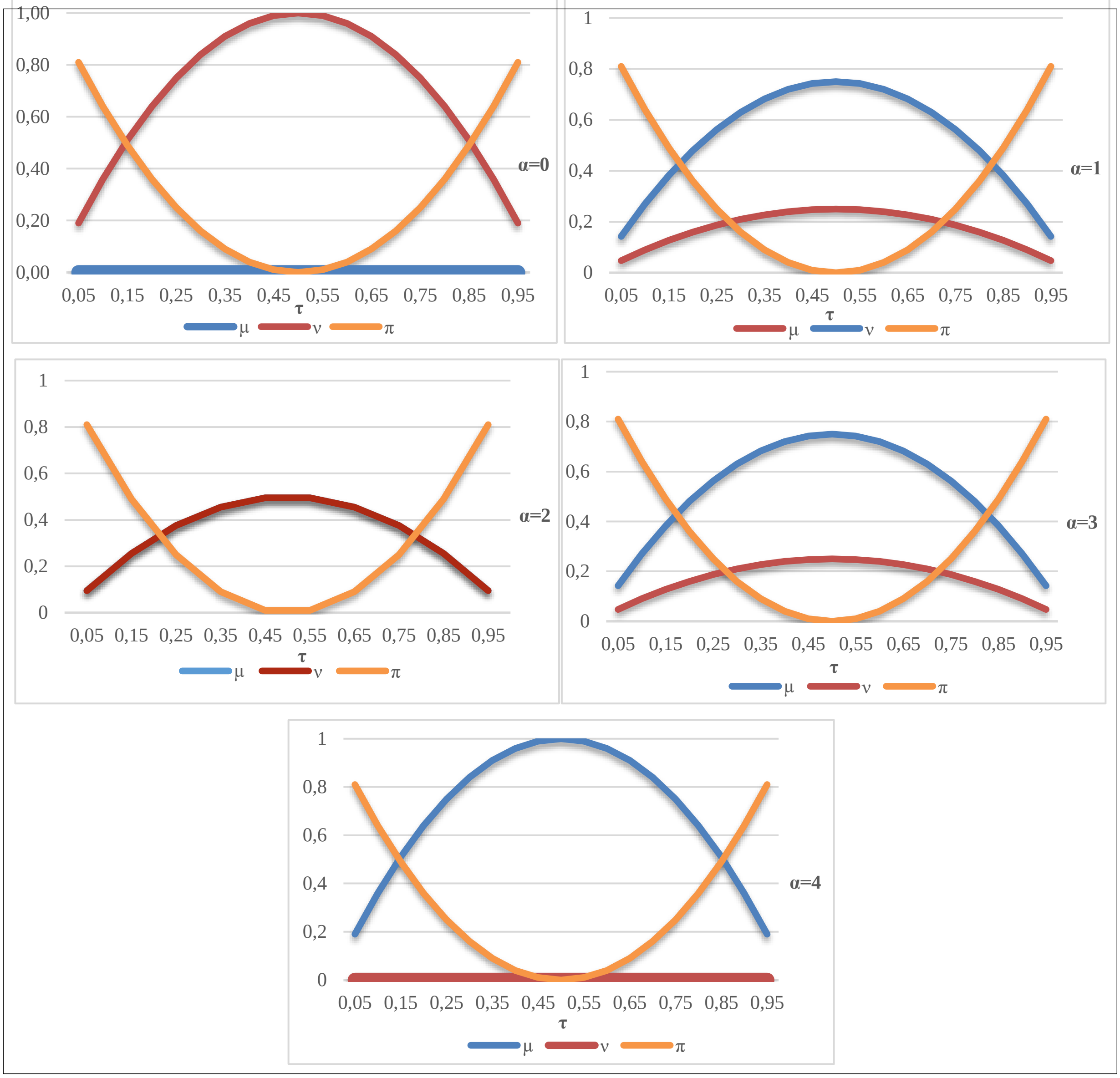

Figure 1: Membership, Non-Membership and Hesitancy Degrees of CINFUSs for α=0, α=1, α=2, α=3 and α=4

Source: Alkan and Kahraman (2023)

$\alpha)\tau^2 \leq 1 = 0 \leq 4\tau - 4\tau^2 \leq 1, for\ \forall\ x\epsilon X$ .. Equation (2) describes the degree of uncertainty in judgment.

$$\boldsymbol{F(\pi,\tau) = 1 - \alpha\tau + \alpha\tau^2 - (4-\alpha)\tau + (4-\alpha)\tau^2 = 1 - 4\left(\tau - \tau^2\right)} \quad (2)$$

The membership, non-membership and hesitancy degrees of CINFUSs are illustrated for $\alpha = 0, 1, 2, 3$ and 4 as in Figure 1.

Definition 2.2. Let $CINFUS_A = \langle(\alpha_A\tau - \alpha_A\tau^2), \left((4-\alpha_A)\tau - (4-\alpha_A)\tau^2\right)\rangle$ and $CINFUS_B = \langle(\alpha_B\tau - \alpha_B\tau^2), \left((4-\alpha_B)\tau - (4-\alpha_B)\tau^2\right)\rangle$ be two CINFUSs, subsequently, the mathematical operations involving these two continuous intuitionistic fuzzy numbers (CINFUNs) are defined as follows:

$$\boldsymbol{CINFUS_A \oplus CINFUS_B = \left\langle\left((\alpha_A+\alpha_B)\tau - (\alpha_A+\alpha_B)\tau^2 - (\alpha_A\tau - \alpha_A\tau^2)(\alpha_B\tau - \alpha_B\tau^2)\right), \left((4-\alpha_A)\tau - (4-\alpha_A)\tau^2\left((4-\alpha_B)\tau - (4-\alpha_B)\tau^2\right)\right)\right\rangle} \quad \textbf{(3)}$$

Figures 2, 3, 4, and 5 show the addition and multiplication operations performed on CINFUNs, as well as the multiplication and expansion of a scalar λ operation for a CINFUN. In Figure $\alpha_A = 2$ and $\alpha_B = 3$ reflect the magnitude of membership functions for $CINFUS_A$ and $CINFUS_B$ respectively. The figures depict the total of membership and non-membership degrees for two CINFUNs, as well as the associated degrees of membership, non-membership, and hesitation.

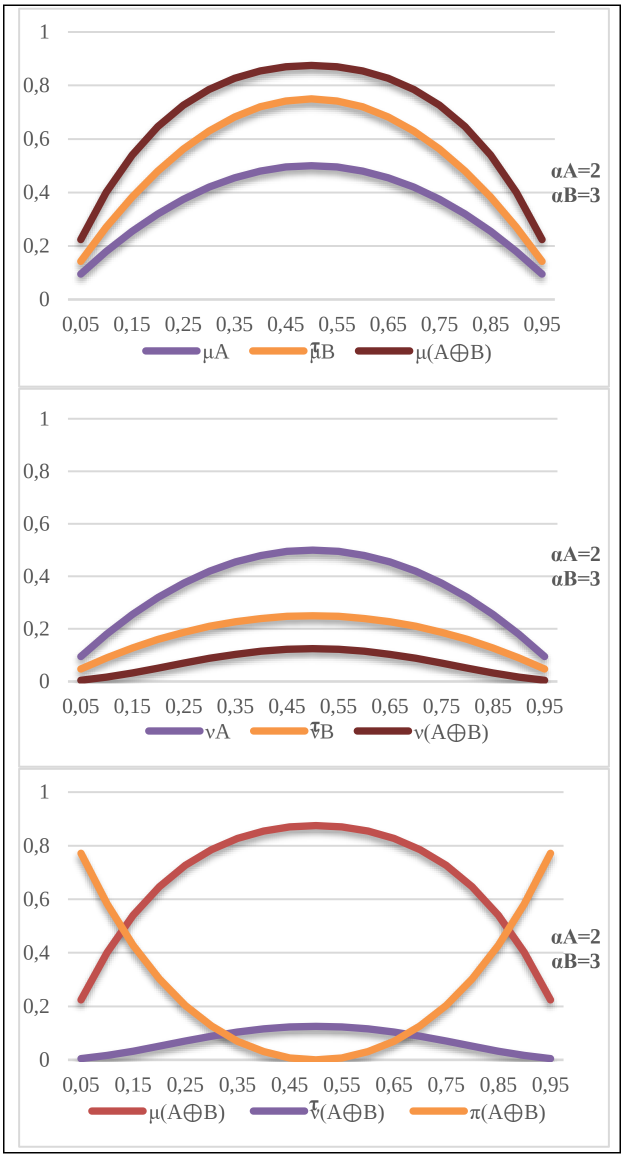

Figure 2: Addition Operation for two CINFUNs
Source: Alkan and Kahraman (2023)

$$CINFUS_A \otimes CINFUS_B = (\alpha_A\tau - \alpha_A\tau^2)(\alpha_B\tau - \alpha_B\tau^2), (4-\alpha_A)\tau - (4-\alpha_A)\tau^2 + (4-\alpha_B)\tau - (4-\alpha_B)\tau^2 - \left((4-\alpha_A)\tau - (4-\alpha_A)\tau^2\right)\left((4-\alpha_B)\tau - (4-\alpha_B)\tau^2\right) = \left\langle\left((\alpha_A+\alpha_B)(\tau-\tau^2)\right), \left((8-\alpha_A-\alpha_B)(\tau-\tau^2) - (4-\alpha_A)(4-\alpha_B)(\tau-\tau^2)^2\right)\right\rangle \quad (4)$$

In Figure 3, $\alpha_A = 3$ and $\alpha_B = 1$ denote the magnitudes of membership functions for, $CINFUS_A$ and $CINFUS_B$ respectively. Figure 3 depicts the multiplication of membership degrees and non-membership degrees for two CINFUNs, as well as the related degrees of membership, non-membership, and hesitancy.

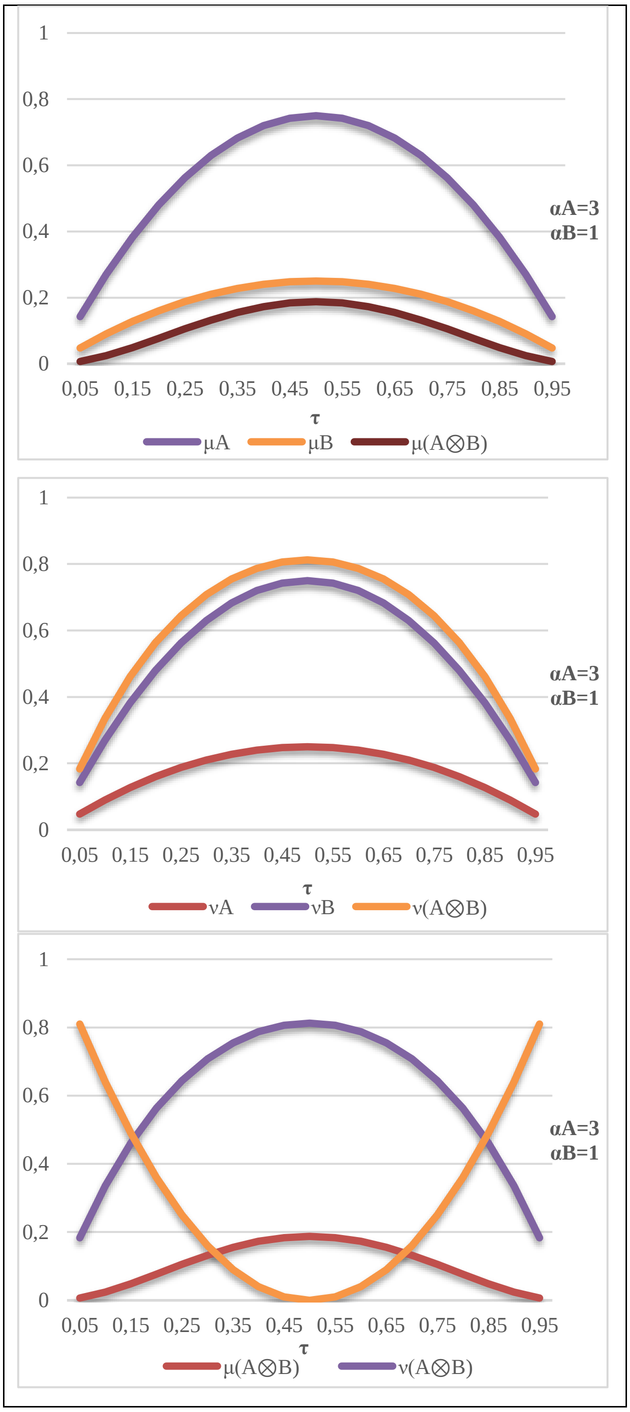

Figure 3: Multiplication Operation for two CINFUNs
Source: Alkan and Kahraman (2023)

$$\lambda \times CINFUS_A = \left\langle\left(1-(1-\alpha_A\tau+\alpha_A\tau^2)^\lambda\right), \left((4-\alpha_A)^\lambda(\tau-\tau^2)^\lambda\right)\right\rangle \quad (5)$$

In Figure 4, $\alpha_A = 2$ and $\lambda = 3$ reflect the magnitude ratings of functions of membership and the value of scaler number for $CINFUS$. Figure 4 illustrates the multiplication of membership functions by the scalar number for CINFUN.

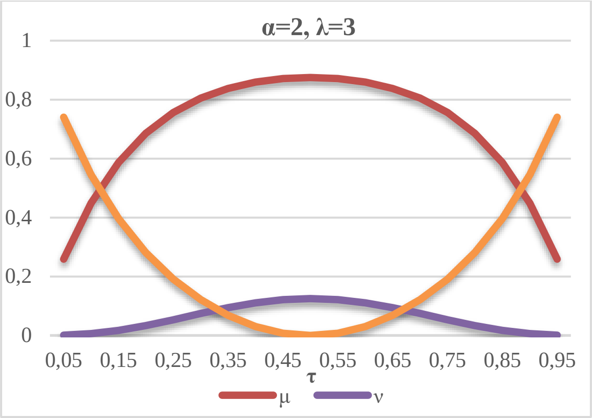

Figure 1: Multiplication by a Scalar of Membership Functions

Source: Alkan and Kahraman (2023)

$$\boldsymbol{CINFUS_A^{\lambda}} = \langle(\boldsymbol{\alpha_A\tau - \alpha_A\tau^2})^{\lambda}, \left(\boldsymbol{1 - \left(1 - (4-\alpha_A)(\tau-\tau^2)\right)^{\lambda}}\right)\rangle \quad \textbf{(6)}$$

In Figure 5, $\alpha_A = 1$ and $\lambda = 5$ represents the magnitude rating of membership functions and the value of scaler number for $CINFUS$. Figure 5 illustrates the effect of increasing CINFUN on the power of the scalar.

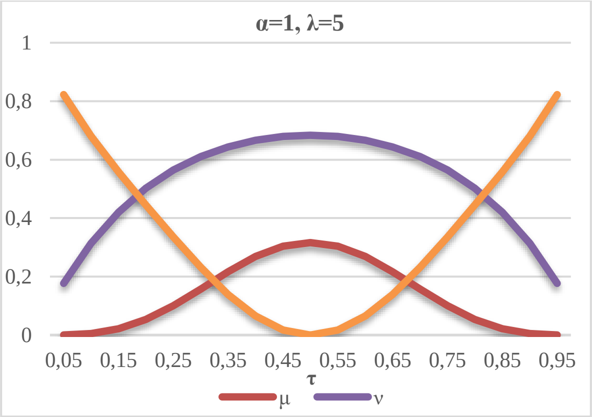

Figure 2: Scalar Number Power of CINFUN

Source: Alkan and Kahraman (2023)

Definition 2.3. Let $\tilde{A}_i = \langle(\alpha\tau - \alpha\tau^2)_i, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_i\rangle, (i = 1,2,\ldots\ldots,n)$ be a set of CINFUSs and $w = (w_1, w_2, \ldots.., w_n)^T$ be weight vector of $\tilde{A}_i$ with $\sum_{i=1}^{n} w_i = 1$, then a continuous intuitionistic fuzzy weighted geometric $(CINFUWG)$ operator is calculated as follows:

$$\boldsymbol{CINFUWG}\,(\widetilde{\boldsymbol{A}}_1, \widetilde{\boldsymbol{A}}_2, \ldots.., \widetilde{\boldsymbol{A}}_n) = \left(\prod_{i=1}^{n}\left(\boldsymbol{\alpha\tau - \alpha\tau^2}\right)_i^{w_i}, \boldsymbol{1} - \prod_{i=1}^{n}\left(\boldsymbol{1} - \left((\boldsymbol{4-\alpha})\boldsymbol{\tau} - (\boldsymbol{4-\alpha})\boldsymbol{\tau^2}\right)_i\right)^{w_i}\right) \quad \textbf{(7)}$$

Definition 2.4. Let $\tilde{A}_i = \langle(\alpha\tau - \alpha\tau^2)_i, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_i\rangle, (i = 1,2,\ldots\ldots,n)$ be a set of CINFUSs and $w = (w_1, w_2, \ldots.., w_n)^T$ be weight vector of $\tilde{A}_i$ with $\sum_{i=1}^{n} w_i = 1$, then a continuous intuitionistic fuzzy weighted average $(CINFUWA)$ operator is calculated as follows:

$$\boldsymbol{CINFUWA}\,(\widetilde{\boldsymbol{A}}_1, \widetilde{\boldsymbol{A}}_2, \ldots.., \widetilde{\boldsymbol{A}}_n) = \left(\boldsymbol{1} - \prod_{i=1}^{n}\left(\boldsymbol{1} - (\boldsymbol{\alpha\tau - \alpha\tau^2})_i\right)^{w_i}, \prod_{i=1}^{n}\left((\boldsymbol{4-\alpha})\boldsymbol{\tau} - (\boldsymbol{4-\alpha})\boldsymbol{\tau^2}\right)_i^{w_i}\right) \quad \textbf{(8)}$$

Definition 2.5. Let $CINFUN = \langle(\alpha\tau - \alpha\tau^2), \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)\rangle$ be an CINFUN, then the score function $S(CINFUN)$ and accuracy function of $CINFUN$, $A(CINFUN)$ can be defined as in Equations (9) and (10), respectively.

$$\boldsymbol{S(CINFUN) = \alpha(\tau-\tau^2) - (4-\alpha)(\tau-\tau^2) = (2\alpha-4)(\tau-\tau^2)} \quad \textbf{(9)}$$

$$\boldsymbol{A(CINFUN) = \alpha(\tau-\tau^2) + (4-\alpha)(\tau-\tau^2) = 4(\tau-\tau^2)} \quad \textbf{(10)}$$

3.2. New CINFU-SWARA-TOPSIS Model

This section demonstrates the integrated SWARA-TOPSIS method based on the notion of Continuous Intuitionistic Fuzzy Sets (CINFUSs) for deriving subjective criteria weights and ranking alternatives using the calculated weights. To apply the proposed technique, follow the procedures explained step by step below.

Step 1. Decide on the alternatives along with the proper criteria to establish the framework. The $A_i = \{A_1, A_2, \ldots, A_m\}$, where $i = 1,2, \ldots, m$, denotes the alternatives, and they are evaluated based on n decision criteria in the set, $C_j = \{C_1, C_2, \ldots, C_m\}$, where $j = 1,2, \ldots, n$. Let $w = (w_1, w_2, \ldots, w_n)$ be the vector set used to indicate the criteria weights, where, $w_j > 0$ and $\sum_{j=1}^{n} w_j = 1$. Decision-makers (DMs), labeled as DM1,

Table 2: Linguistic Scale for Criterion Weighting

	CINFUNs	
	μ	***ϑ***
Absolutely less important than – (ALI)	0τ-0τ^2	4τ-4 τ^2
Very strongly less important than – (VSLI)	0.5τ-0.5τ^2	3.5τ-3.5τ^2
Strongly less important than – (StLI)	τ-τ^2	3τ-3τ^2
Slightly less important than – (SlLI)	1.5τ-1.5τ^2	2.5τ-2.5τ^2
Exactly equal importance – (EEI)	2τ-2τ^2	2τ-2τ^2
Slightly more important than – (SlMI)	2.5τ-2.5τ^2	1.5τ-1.5τ^2
Strongly more important than – (StMI)	3τ-3τ^2	τ-τ^2
Very strongly more important than – (VSMI)	3.5τ-3.5τ^2	0.5τ-0.5τ^2
Absolutely more important than – (AMI)	4τ-4τ^2	0τ-0τ^2

Source: Alkan and Kahraman (2023)

DM2, ..., DMk, are professionals in their respective disciplines who make decisions.

Step 2. Use the SWARA tool to determine the subjective weight w_j^s of j^{th}criterion. The initial step in the SWARA weighting method is to establish the rating of each criterion. The CINFUN-SWARA school has the following programs:

Step 2.1. The DMs need to assess the criteria using the linguistic scale presented in Table 2.

Step 2.2. Obtain the CINFUN-score value for every single criterion with Equation 9.

Step 2.3. Rank the criteria in descending order based on the CINFUN-score values obtained from the decision-makers' reports.

Step 2.4. Obtain the relative importance (s_j) of criterion by comparing it to the *(j-1)th* criterion, which is favored in the second place.

Step 2.5. Compute the comparative parameter with Equation (11) as:

$$\boldsymbol{k_j = \begin{cases} 1, & j = 1 \\ s_j + 1, & j > 1 \end{cases}} \tag{11}$$

Step 2.6. Obtain the weights *(p_j)* of the attribute as:

$$\boldsymbol{p_j = \begin{cases} 1, & j = 1 \\ \dfrac{p_j - 1}{k_j}, & j > 1 \end{cases}} \tag{12}$$

Step 2.7. Calculate the normalized weight of the criteria as:

$$\boldsymbol{w_j^s = \frac{p_j}{\sum_{j=1}^{n} p_j}, j = 1, 2, \dots, n} \tag{13}$$

Step 3. Ranking alternatives employing the TOPSIS approach, which is based on CINFUSs. For execution of the developed methodology, perform the sub-procedures detailed below.

Step 3.1. Create Continuous Intuitionistic Fuzzy (CINFU) decision-making matrices that take into account each decision-maker's views incorporating the linguistic scale presented in Table 3.

Table 3: Linguistic Scale for Evaluating Options Based on Criteria

	CINFUNs	
	μ	**ϑ**
Absoluτely Low Value – (ALV)	$0\tau\text{-}0\tau^2$	$4\tau\text{-}4\ \tau^2$
Very Low Value – (VLV)	$0.5\tau\text{-}0.5\tau^2$	$3.5\tau\text{-}3.5\tau^2$
Low Value – (LV)	$\tau\text{-}\tau^2$	$3\tau\text{-}3\tau^2$
Slighτly Low Value – (SLV)	$1.5\tau\text{-}1.5\tau^2$	$2.5\tau\text{-}2.5\tau^2$
Medium Value – (MV)	$2\tau\text{-}2\tau^2$	$2\tau\text{-}2\tau^2$
Slighτly High Value – (SHV)	$2.5\tau\text{-}2.5\tau^2$	$1.5\tau\text{-}1.5\tau^2$
High Value – (HV)	$3\tau\text{-}3\tau^2$	$\tau\text{-}\tau^2$
Very High Value – (VHV)	$3.5\tau\text{-}3.5\tau^2$	$0.5\tau\text{-}0.5\tau^2$
Absoluτely High Value – (AHV)	$4\tau\text{-}4\tau^2$	$0\tau\text{-}0\tau^2$

Source: Alkan and Kahraman (2023)

The linguistic decision matrices are transformed into CINFUNs. The CINFU decision matrix $\tilde{X}_{\mathrm{k}} = (\tilde{x}_{\mathrm{ijk}})_{n\times m}$according to *kth DM* is shown in Table 4. Here, $\tilde{X}_{\mathrm{k}} = (\tilde{x}_{\mathrm{ijk}})_{n\times m}$ in which $\tilde{x}_{\mathrm{ijk}} = \left((\alpha\tau - \alpha\tau^2)_{ijk}, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_{ijk}\right)$ represents the CINFU value of alternative A_i in terms of to the criterion C_j of *kth DM*.

Step 3.2. Built the aggregated CINFU decision matrix. The CINFUWG operation is used to aggregate the decision-making processes of separate DMs into a unified matrix, as stated in Equation (7). The aggregated CINFU decision matrix ($\tilde{X}_{\mathrm{k}}$) is constructed based on each τ value, which ranges from zero to one, as specified by the expert and provided in Table 5. Here, $\tilde{X}_{\mathrm{k}} = (\tilde{x}_{\mathrm{ijk}})_{n\times m}$ in which $\tilde{x}_{\mathrm{ij}} = \left(\mu_{ij,\tau}, \vartheta_{ij,\tau}\right)$ represents the aggregated CINFUN of *ith* alternative in accordance with *jth* criterion.

Table 5: Aggregated CINFU Decision Matrix

Criteria	**Alternatives**		
	A$_1$	**...**	**A$_m$**
C$_1$	$(\mu_{11,\tau}, \vartheta_{11,\tau})$	⋯	$(\mu_{1m,\tau}, \vartheta_{1m,\tau})$
C$_2$	$(\mu_{21,\tau}, \vartheta_{21,\tau})$	⋯	$(\mu_{2m,\tau}, \vartheta_{2m,\tau})$
⋮	⋮	⋱	⋮
C$_n$	$(\mu_{n1,\tau}, \vartheta_{n1,\tau})$	⋯	$(\mu_{nm,\tau}, \vartheta_{nm,\tau})$

Source: Author’s own elaboration

Step 3.3. Create the weighted decision matrix. After determining criterion weights with CINFUN-SWARA in the second phase and identifying CINFU ratings for alternatives, the weighted CINFU decision matrix $\tilde{\mathfrak{H}} = (\tilde{\zeta})_{n\times m}$ is obtained for each τ value utilizing the Equation (14).

$$\boldsymbol{\tilde{\mathfrak{H}} = \left|\tilde{\zeta}_{ij}\right| = \left|\mathrm{w}_j\tilde{x}_{ij}\right|} \tag{14}$$

Where $\mathrm{w}_j\tilde{x}_{ij} = \left(\mu_{\xi ij,\ \tau}, \vartheta_{\xi ij,\ \tau}\right)$ reflects the weighted CINFUN of *ith* alternative with regard to *jth* criterion.

Table 4: A Decision Matrix Based on CINFUNs for the kth DM

Criteria	**Alternatives**		
	A$_1$	**...**	**A$_m$**
C$_1$	$\left((\alpha\tau - \alpha\tau^2)_{11k}, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_{11k}\right)$	⋯	$\left((\alpha\tau - \alpha\tau^2)_{1mk}, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_{1mk}\right)$
C$_2$	$\left((\alpha\tau - \alpha\tau^2)_{21k}, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_{21k}\right)$	⋯	$\left((\alpha\tau - \alpha\tau^2)_{2mk}, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_{2mk}\right)$
⋮	⋮	⋱	⋮
C$_n$	$\left((\alpha\tau - \alpha\tau^2)_{n1k}, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_{n1k}\right)$	⋯	$\left((\alpha\tau - \alpha\tau^2)_{nmk}, \left((4-\alpha)\tau - (4-\alpha)\tau^2\right)_{nmk}\right)$

Source: Author’s own elaboration

$$\begin{aligned}\boldsymbol{CINFU-PIS} &= \boldsymbol{\delta^{*}}\\ &= \left\{\left\langle\left((\mathbf{1},\mathbf{0}), \boldsymbol{for\ benefit\ criteria}\right),\left((\mathbf{0},\mathbf{1}), \boldsymbol{for\ cost\ criteria}\right)\right\rangle\right\}\\ &= \left\{\tilde{\zeta}_1^{*},\tilde{\zeta}_2^{*},\ldots,\tilde{\zeta}_n^{*}\right\}, \boldsymbol{for\ i} = \mathbf{1},\mathbf{2},\ldots,\boldsymbol{m}\end{aligned} \tag{15}$$

$$\begin{aligned}\boldsymbol{CINFU-NIS} &= \boldsymbol{\delta^{-}}\\ &= \left\{\left\langle\left((\mathbf{0},\mathbf{1}), \boldsymbol{for\ benefit\ criteria}\right),\left((\mathbf{1},\mathbf{0}), \boldsymbol{for\ cost\ criteria}\right)\right\rangle\right\}\\ &= \left\{\tilde{\zeta}_1^{-},\tilde{\zeta}_2^{-},\ldots,\tilde{\zeta}_n^{-}\right\}, \boldsymbol{for\ i} = \mathbf{1},\mathbf{2},\ldots,\boldsymbol{m}\end{aligned} \tag{16}$$

$$\Delta_{i,\tau}^{*} = \sqrt{\frac{1}{2n}\sum_{j}^{n}\left(\left(\mu_{ij,\tau}-1\right)^2,\left(\vartheta_{ij,\tau}-0\right)^2\right)}\ for\ i = 1,2,\ldots,m \tag{18}$$

$$\Delta_{i,\tau}^{-} = \sqrt{\frac{1}{2n}\sum_{j}^{n}\left(\left(\mu_{ij,\tau}-0\right)^2,\left(\vartheta_{ij,\tau}-1\right)^2\right)}\ for\ i = 1,2,\ldots,m \tag{19}$$

Sτep 3.4: Identify the CINFU Positive Ideal Solution (CINFU-PIS) and CINFU Negative Ideal Solution (CINFU-NIS) based on weighted CINFU decision matrix. In this paper, Equations (15) and (16) are employed for CINFU-PIS and CINFU-NIS, respectively (For more detailed information, see Alkan and Kahraman, 2023).

Step 3.5. Calculate separation measures by measuring the differences between the positive and negative ideal solutions (δ-∗ and δ-−). The separation measures of each alternative are determined for each τ value based on the weighted CINFU decision matrix by using CINFU Euclidean distances presented for positive and negative ideal solutions in Equations. (18 and 19), respectively.

Step 3.6. Calculate the relative proximity of each alternative for each τ value to ideal solution Υ_i by utilizing the Equation (20).

$$\boldsymbol{\Upsilon_{i,\tau}} = \frac{\Delta_{i,\tau}^{-}}{\Delta_{i,\tau}^{*}+\Delta_{i,\tau}^{-}}\ \boldsymbol{for\ i} = \mathbf{1},\mathbf{2},\ldots,\boldsymbol{m} \tag{20}$$

Step 3.7. Rank the alternatives based on the final scores of $\Upsilon_{i,\tau}$. The most attractive alternative(s) are chosen in decreasing order of their relative closeness ($\Upsilon_{i,\tau}$) values for each τ value.

4. Numerical Application

This section presents a numerical example demonstrating the execution steps of the CINFU-SWARA and CINFU-TOPSIS techniques in identifying the best hotel for horizontal alliances on behalf of hotels and airlines. The CINFU-SWARA procedure is used for calculating criterion weights to analyze the alternatives. The CINFU-TOPSIS procedure, originally developed by Alkan and Kahraman (2023), serves to determine final scores and ranks for alternative hotels.

Problem Definition

Everyday life challenges with decision-making involve complicated scenarios with ambiguous outcomes that need the evaluation of several conditions and options concurrently. In today's fiercely competitive airline sector, collaborations have become essential strategic plays for survival. Horizontal alliances between hotels and airlines (HAAs), which are established by airlines depending on their economic scope and scale, have emerged as key steps for airlines to improve their levels of service and accommodate more passengers.

The factors to consider when making decisions for Horizontal Alliances between hotels and airlines (HAAs) include as follows, based on both the literature research and expert opinions:

Scale and scope possibility: Concerning studies conducted by Liou (2012) and Oum et al. (2000), the HAA enhances airline share of the market and earnings. The partnership enables an airline with considerable economic scale and extensive operational capability to deliver more services through HAA and attract more customers.

Brand value: The HAA can strengthen the airline's benefits by increasing brand recognition and value for the product. According to Liou (2012), Fan et al. (2001), Stafford (1994), and Geringer (1991), promoting local brand recognition and encouraging research and development for distinctive local products or services is very important for airlines. Airlines could partner with hotels to strengthen local brand presence and get better recognition and perception in large markets. This partnership contains a chance to come up with products and services tailored to local culture and characteristics, providing customers with greater customization and unique experiences.

Tourism attraction: The term "touristic attraction" refers to the unique attractiveness of a place or destination for tourists. Alliances with hotels located in advantageous places allow airlines to reach more customers by selling packages that provide exclusive access, discounts, or unique experiences at these locations (Fu et al., 2020).

Operating cost: The HAA ought to lower the airline's operational cost, information exchange, and communication costs (Bilotkach and Hüschelrath, 2012; Liou et al., 2011; Rhoades and Lush, 1997).

Industrial conditions: The achievable value of a hotel for a Horizontal Alliance within hotels and airlines (HAA) varies based on local hotel business circumstances, including the growth of cities (expansion possibility), hotel supply, and foreign and domestic travelers (Yang et al., 2015; Adam and Amuquandoh, 2014; Demirel et al., 2010; Robert and Ernest, 1992). As stated by Newell and Seabrook (2006), key considerations to consider while assessing a hotel are industrial supply, demand fluctuation, location features, and domestic tourists.

Problem Solution

The following CINFU-SWARA phases are used to calculate the weights of the criteria for selecting alternative hotels for HAA:

Step 1. After performing in-depth literature research and considering the suggestions and opinions of experts, the criteria and alternatives outlined in Section 3.1 are used in the process of selecting the most suitable alternative. Three decision-making experts, labeled DM 1, DM 2, and DM 3, were selected from academics and airline industry specialists. These experts specialize in multi-criterion decision-making in fuzzy environments and are tasked with evaluating the provided criteria and alternatives. In this study, DM weights, which represent the decision-maker's knowledge and experience levels, were given equal weights of 0.34, 0.33, and 0.33, respectively.

Step 2. During computing the weight of each criterion employing CINFU-SWARA, the professional background of the expert was vital. In this case, three decision-makers, denoted as DM 1, DM 2, and DM 3, each with equal weight, shared their points of view. The linguistic scale from Table 2 was used to rank the criteria depending on their level of relevance, as seen in Table 6.

Table 6: The Magnitude of Criteria in the Form of CINFU Linguistic Variables

Criteria	DM1	DM2	DM3
C1	EEI	SlLI	SlLI
C2	VSMI	VSMI	StMI
C3	AMI	VSMI	VSMI
C4	SlLI	SlLI	StLI
C5	SlMI	StMI	EEI

Source: Author's own elaboration

Step 3. The linguistic reviews of each DM are then converted into their corresponding CINFUNs using the scale provided in Table 3, as shown in Table 7.

Step 4. The CINFUWG execution, as described in Equation (7), was carried out to get an aggregated matrix of individual DM evaluations. The Aggregated CINFU Decision Matrix for Alternatives across criteria is compliant for τ values that vary from 0 to 1, with increasing of 0.1, shown in Table 8.

Table 8: The Aggregated CINFU Decision Matrix for Alternatives

	τ	$(\mu_{nm,\tau}, \vartheta_{nm,\tau})$	Score Value
C1	0.1	(0.150, 0.208)	0.247
	0.2	(0.268, 0.370)	0.365
	0.3	(0.352, 0.486)	0.409
	0.4	(0.403, 0.556)	0.419
	0.5	(0.420, 0.579)	0.420
	0.6	(0.403, 0.556)	0.419
	0.7	(0.352, 0.486)	0.409
	0.8	(0.268, 0.370)	0.365
	0.9	(0.150, 0.208)	0.247
C2	0.1	(0.300, 0.056)	0.493
	0.2	(0.535, 0.100)	0.730
	0.3	(0.704, 0.131)	0.819
	0.4	(0.807, 0.150)	0.841
	0.5	(0.842, 0.157)	0.842
	0.6	(0.807, 0.150)	0.841
	0.7	(0.704, 0.131)	0.819
	0.8	(0.535, 0.100)	0.730
	0.9	(0.300, 0.056)	0.493
C3	0.1	(0.330, 0)	0.551
	0.2	(0.589, 0)	0.831
	0.3	(0.776, 0)	0.950
	0.4	(0.900, 0)	0.990
	0.5	(1, 0)	1
	0.6	(0.900, 0)	0.990
	0.7	(0.776, 0)	0.950
	0.8	(0.589, 0)	0.831
	0.9	(0.330, 0)	0.551
C4	0.1	(0.120, 0.238)	0.197
	0.2	(0.214, 0.424)	0.291
	0.3	(0.281, 0.557)	0.327
	0.4	(0.322, 0.637)	0.335
	0.5	(0.336, 0.663)	0.336
	0.6	(0.322, 0.637)	0.335
	0.7	(0.281, 0.557)	0.327
	0.8	(0.214, 0.424)	0.291
	0.9	(0.120, 0.238)	0.197
C5	0.1	(0.225, 0.129)	0.371
	0.2	(0.403, 0.230)	0.551
	0.3	(0.532, 0.302)	0.620
	0.4	(0.612, 0.346)	0.637
	0.5	(0.639, 0.360)	0.639
	0.6	(0.612, 0.346)	0.637
	0.7	(0.532, 0.302)	0.620
	0.8	(0.403, 0.230)	0.551
	0.9	(0.225, 0.129)	0.371

Source: Author's own elaboration

As stated in Alkan and Kahraman's (2023) study, while specifying membership and non-membership in CINFUNs, a continuous and non-linear distribution assumption is put forward and it is presumed that the coefficients reduce as we move away from the center in a bell-shaped distribution. To calculate weights employing

Table 7: Corresponding CINFUNs of the DM Assessments

	DM1		DM2		DM3	
C1	$2\tau-2\tau^2$	$2\tau-2\tau^2$	$1.5\tau-1.5\tau^2$	$2.5\tau-2.5\tau^2$	$1.5\tau-1.5\tau^2$	$2.5\tau-2.5\tau^2$
C2	$3.5\tau-3.5\tau^2$	$0.5\tau-0.5\tau^2$	$3.5\tau-3.5\tau^2$	$0.5\tau-0.5\tau^2$	$3\tau-3\tau^2$	$\tau-\tau^2$
C3	$4\tau-4\tau^2$	$0\tau-0\tau^2$	$3.5\tau-3.5\tau^2$	$0.5\tau-0.5\tau^2$	$3.5\tau-3.5\tau^2$	$0.5\tau-0.5\tau^2$
C4	$1.5\tau-1.5\tau^2$	$2.5\tau-2.5\tau^2$	$1.5\tau-1.5\tau^2$	$2.5\tau-2.5\tau^2$	$\tau-\tau^2$	$3\tau-3\tau^2$
C5	$2.5\tau-2.5\tau^2$	$1.5\tau-1.5\tau^2$	$3\tau-3\tau^2$	$\tau-\tau^2$	$2\tau-2\tau^2$	$2\tau-2\tau^2$

Source: Author's own elaboration

CINFU-SWARA, score values equivalent to 0.5 tau are used. The scholar can select the appropriate score values for the τ value to be used.

Step 5. Using the traditional SWARA structure outlined in Equations (11-13), the criterion having the greatest influence was given a higher rank, whereas the one with the lowest importance was given a lower rank. Table 9 shows the attribute weights obtained by the CINFU-SWARA methodology. The final weights for the criteria are displayed below:

Table 9: Criterion Weights Based on CINFU-SWARA

Criteria	Score Values	s_j	k_j	p_j	w_j
C3	1		1	1	0.202
C2	0.842	0.157	1.157	0.864	0.175
C5	0.639	0.203	1.203	0.961	0.194
C1	0.420	0.218	1.218	0.987	0.200
C4	0.336	0.084	1.084	1.123	0.227

Source: Author's own elaboration

Following calculation of the criteria weights, the following phases of the suggested methodology should be performed for calculating and ranking the final scores for alternative hotels:

Step 6. The DMs assess the alternatives in regard to the given objectives and criteria based on the CINFU linguistic scale, which is presented by Table 2. Linguistic decision-making matrices based on DM evaluations are presented in Table 10.

Table 10: Linguistic Decision-Making Matrices Based on DM Assessments

		C1	C2	C3	C4	C5
DM1	H1	LV	ALV	SHV	SHV	MV
	H2	AHV	VHV	HV	MV	VLV
	H3	SHV	VHV	SHV	LV	MV
	H4	MV	LV	MV	HV	SLV
	H5	HV	MV	LV	SLV	SHV
	H6	HV	SHV	VLV	MV	SLV
	H7	SHV	HV	MV	HV	VHV
	H8	VHV	SLV	HV	HV	ALV
	H9	HV	VHV	SLV	LV	HV
	H10	HV	LV	VHV	HV	SLV
	H1	MV	VLV	MV	HV	HV
	H2	VHV	HV	HV	SLV	LV
	H3	SLV	AHV	MV	VLV	VLV
	H4	HV	VLV	HV	VHV	MV
	H5	MV	SHV	VLV	LV	HV
	H6	MV	MV	LV	VHV	LV
	H7	HV	VHV	SLV	LV	HV
	H8	HV	LV	VHV	HV	SLV
	H9	VLV	SHV	HV	MV	HV
	H10	SHV	SHV	LV	HV	VHV
	H1	LV	MV	VHV	MV	HV
	H2	LV	VHV	LV	MV	SLV
	H3	VHV	SLV	SLV	MV	VHV
	H4	ALV	VHV	HV	HV	SLV
	H5	HV	LV	SLV	VHV	HV
	H6	HV	VLV	HV	MV	MV
	H7	AHV	LV	SLV	VHV	VLV
	H8	SLV	HV	HV	SHV	MV
	H9	VLV	VHV	HV	SHV	VHV
	H10	MV	MV	VLV	VHV	HV

Source: Author's own elaboration

The linguistic assessments of each DM are converted into their corresponding CINFUNs using the scale provided in Table 3. The CINFU decision matrix for each DM is presented in Table 11.

Table 11: The CINFU Decision Matrix for Each DM

		C1	C2	C3	C4	C5
DM1	H1	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(0\tau-0\tau^2, 4\tau-4\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$
	H2	$(4\tau-4\tau^2, 0\tau-0\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$
	H3	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$
	H4	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$
	H5	$(3\tau-3\tau^2, \tau-\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$
	H6	$(3\tau-3\tau^2, \tau-\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$
	H7	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$
	H8	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(0\tau-0\tau^2, 4\tau-4\tau^2)$
	H9	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$
	H10	$(3\tau-3\tau^2, \tau-\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$
	H1	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$
	H2	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$
	H3	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(4\tau-4\tau^2, 0\tau-0\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$
	H4	$(3\tau-3\tau^2, \tau-\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$
	H5	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$
	H6	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$
	H7	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$
	H8	$(3\tau-3\tau^2, \tau-\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$
	H9	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$
	H10	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$
	H1	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$
	H2	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$
	H3	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$
	H4	$(0\tau-0\tau^2, 4\tau-4\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$
	H5	$(3\tau-3\tau^2, \tau-\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$
	H6	$(3\tau-3\tau^2, \tau-\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$
	H7	$(4\tau-4\tau^2, 0\tau-0\tau^2)$	$(\tau-\tau^2, 3\tau-3\tau^2)$	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$
	H8	$(1.5\tau-1.5\tau^2, 2.5\tau-2.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$
	H9	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$	$(2.5\tau-2.5\tau^2, 1.5\tau-1.5\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$
	H10	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(2\tau-2\tau^2, 2\tau-2\tau^2)$	$(0.5\tau-0.5\tau^2, 3.5\tau-3.5\tau^2)$	$(3.5\tau-3.5\tau^2, 0.5\tau-0.5\tau^2)$	$(3\tau-3\tau^2, \tau-\tau^2)$

Source: Author's own elaboration

Table 12: Aggregated CINFU Decision Matrix for τ Values

	τ	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
C1	0.1	(0.113, 0.241)	(0.218, 0.112)	(0.212, 0.138)	(0, 0.217)	(0.236, 0.120)	(0.236, 0.120)	(0.279, 0.077)	(0.226, 0.122)	(0.082, 0.245)	(0.222, 0.135)
	0.2	(0.201, 0.431)	(0.387, 0.215)	(0.377, 0.251)	(0, 0.408)	(0.419, 0.216)	(0.419, 0.216)	(0.496, 0.140)	(0.402, 0.224)	(0.147, 0.451)	(0.395, 0.242)
	0.3	(0.263, 0.570)	(0.508, 0.305)	(0.495, 0.336)	(0, 0.580)	(0.551, 0.286)	(0.551, 0.286)	(0.651, 0.186)	(0.528, 0.303)	(0.193, 0.615)	(0.518, 0.319)
	0.4	(0.301, 0.656)	(0.581, 0.370)	(0.566, 0.391)	(0, 0.747)	(0.629, 0.329)	(0.629, 0.329)	(0.744, 0.215)	(0.603, 0.353)	(0.220, 0.728)	(0.593, 0.366)
	0.5	(0.314, 0.685)	(0.605, 0.394)	(0.590, 0.409)	(0, 1)	(0.656, 0.343)	(0.656, 0.343)	(0.775, 0.224)	(0.628, 0.371)	(0.229, 0.770)	(0.617, 0.382)
	0.6	(0.301, 0.656)	(0.581, 0.370)	(0.566, 0.391)	(0, 0.747)	(0.629, 0.329)	(0.629, 0.329)	(0.744, 0.215)	(0.603, 0.353)	(0.220, 0.728)	(0.593, 0.366)
	0.7	(0.263, 0.570)	(0.508, 0.305)	(0.495, 0.336)	(0, 0.580)	(0.551, 0.286)	(0.551, 0.286)	(0.651, 0.186)	(0.528, 0.303)	(0.193, 0.615)	(0.518, 0.319)
	0.8	(0.201, 0.431)	(0.387, 0.215)	(0.377, 0.251)	(0, 0.408)	(0.419, 0.216)	(0.419, 0.216)	(0.496, 0.140)	(0.402, 0.224)	(0.147, 0.451)	(0.395, 0.242)
	0.9	(0.113, 0.241)	(0.218, 0.112)	(0.212, 0.138)	(0, 0.217)	(0.236, 0.120)	(0.236, 0.120)	(0.279, 0.077)	(0.226, 0.122)	(0.082, 0.245)	(0.222, 0.135)
C2	0.1	(0, 0.289)	(0.299, 0.060)	(0.248, 0.094)	(0.108, 0.218)	(0.154, 0.196)	(0.122, 0.213)	(0.197, 0.140)	(0.148, 0.198)	(0.281, 0.075)	(0.153, 0.197)
	0.2	(0, 0.525)	(0.532, 0.107)	(0.442, 0.178)	(0.192, 0.405)	(0.274, 0.354)	(0.218, 0.388)	(0.351, 0.261)	(0.263, 0.360)	(0.501, 0.136)	(0.272, 0.356)
	0.3	(0, 0.710)	(0.698, 0.141)	(0.580, 0.246)	(0.252, 0.556)	(0.359, 0.471)	(0.286, 0.526)	(0.461, 0.359)	(0.346, 0.482)	(0.657, 0.180)	(0.357, 0.474)
	0.4	(0, 0.852)	(0.798, 0.161)	(0.663, 0.292)	(0.288, 0.660)	(0.411, 0.546)	(0.327, 0.621)	(0.527, 0.426)	(0.395, 0.560)	(0.751, 0.207)	(0.408, 0.548)
	0.5	(0, 1)	(0.831, 0.168)	(0.691, 0.308)	(0.300, 0.699)	(0.428, 0.571)	(0.341, 0.658)	(0.549, 0.450)	(0.412, 0.587)	(0.783, 0.216)	(0.425, 0.574)
	0.6	(0, 0.852)	(0.798, 0.161)	(0.663, 0.292)	(0.288, 0.660)	(0.411, 0.546)	(0.327, 0.621)	(0.527, 0.426)	(0.395, 0.560)	(0.751, 0.207)	(0.408, 0.548)
	0.7	(0, 0.710)	(0.698, 0.141)	(0.580, 0.246)	(0.252, 0.556)	(0.359, 0.471)	(0.286, 0.526)	(0.461, 0.359)	(0.346, 0.482)	(0.657, 0.180)	(0.357, 0.474)
	0.8	(0, 0.525)	(0.532, 0.107)	(0.442, 0.178)	(0.192, 0.405)	(0.274, 0.354)	(0.218, 0.388)	(0.351, 0.261)	(0.263, 0.360)	(0.501, 0.136)	(0.272, 0.356)
	0.9	(0, 0.289)	(0.299, 0.060)	(0.248, 0.094)	(0.108, 0.218)	(0.154, 0.196)	(0.122, 0.213)	(0.197, 0.140)	(0.148, 0.198)	(0.281, 0.075)	(0.153, 0.197)
C3	0.1	(0.233, 0.121)	(0.187, 0.153)	(0.176, 0.180)	(0.235, 0.121)	(0.081, 0.270)	(0.102, 0.231)	(0.148, 0.209)	(0.284, 0.075)	(0.213, 0.138)	(0.109, 0.216)
	0.2	(0.415, 0.219)	(0.334, 0.282)	(0.313, 0.322)	(0.418, 0.218)	(0.145, 0.484)	(0.181, 0.424)	(0.264, 0.373)	(0.505, 0.134)	(0.379, 0.250)	(0.194, 0.402)
	0.3	(0.545, 0.291)	(0.438, 0.384)	(0.412, 0.425)	(0.548, 0.288)	(0.190, 0.640)	(0.238, 0.575)	(0.347, 0.491)	(0.662, 0.176)	(0.497, 0.335)	(0.255, 0.552)
	0.4	(0.622, 0.336)	(0.501, 0.453)	(0.470, 0.488)	(0.627, 0.331)	(0.218, 0.738)	(0.272, 0.678)	(0.396, 0.562)	(0.757, 0.202)	(0.568, 0.389)	(0.292, 0.656)
	0.5	(0.648, 0.351)	(0.521, 0.478)	(0.490, 0.509)	(0.653, 0.346)	(0.227, 0.772)	(0.283, 0.716)	(0.413, 0.586)	(0.789, 0.210)	(0.592, 0.407)	(0.304, 0.695)
	0.6	(0.622, 0.336)	(0.501, 0.453)	(0.470, 0.488)	(0.627, 0.331)	(0.218, 0.738)	(0.272, 0.678)	(0.396, 0.562)	(0.757, 0.202)	(0.568, 0.389)	(0.292, 0.656)
	0.7	(0.545, 0.291)	(0.438, 0.384)	(0.412, 0.425)	(0.548, 0.288)	(0.190, 0.640)	(0.238, 0.575)	(0.347, 0.491)	(0.662, 0.176)	(0.497, 0.335)	(0.255, 0.552)
	0.8	(0.415, 0.219)	(0.334, 0.282)	(0.313, 0.322)	(0.418, 0.218)	(0.145, 0.484)	(0.181, 0.424)	(0.264, 0.373)	(0.505, 0.134)	(0.379, 0.250)	(0.194, 0.402)
	0.9	(0.233, 0.121)	(0.187, 0.153)	(0.176, 0.180)	(0.235, 0.121)	(0.081, 0.270)	(0.102, 0.231)	(0.148, 0.209)	(0.284, 0.075)	(0.213, 0.138)	(0.109, 0.216)
C4	0.1	(0.221, 0.135)	(0.163, 0.195)	(0.09, 0.257)	(0.284, 0.075)	(0.156, 0.185)	(0.216, 0.137)	(0.197, 0.140)	(0.254, 0.105)	(0.153, 0.197)	(0.284, 0.075)
	0.2	(0.394, 0.242)	(0.291, 0.347)	(0.16, 0.462)	(0.505, 0.134)	(0.277, 0.340)	(0.384, 0.248)	(0.351, 0.261)	(0.451, 0.187)	(0.272, 0.356)	(0.505, 0.134)
	0.3	(0.517, 0.320)	(0.381, 0.456)	(0.21, 0.615)	(0.662, 0.176)	(0.364, 0.460)	(0.505, 0.330)	(0.461, 0.359)	(0.593, 0.246)	(0.357, 0.474)	(0.662, 0.176)
	0.4	(0.591, 0.367)	(0.436, 0.523)	(0.24, 0.714)	(0.757, 0.202)	(0.416, 0.538)	(0.577, 0.381)	(0.527, 0.426)	(0.677, 0.281)	(0.408, 0.548)	(0.757, 0.202)
	0.5	(0.616, 0.383)	(0.454, 0.545)	(0.25, 0.75)	(0.789, 0.210)	(0.433, 0.566)	(0.601, 0.398)	(0.549, 0.450)	(0.706, 0.293)	(0.425, 0.574)	(0.789, 0.210)
	0.6	(0.591, 0.367)	(0.436, 0.523)	(0.24, 0.714)	(0.757, 0.202)	(0.416, 0.538)	(0.577, 0.381)	(0.527, 0.426)	(0.677, 0.281)	(0.408, 0.548)	(0.757, 0.202)
	0.7	(0.517, 0.320)	(0.381, 0.456)	(0.21, 0.615)	(0.662, 0.176)	(0.364, 0.460)	(0.505, 0.330)	(0.461, 0.359)	(0.593, 0.246)	(0.357, 0.474)	(0.662, 0.176)
	0.8	(0.394, 0.242)	(0.291, 0.347)	(0.16, 0.462)	(0.505, 0.134)	(0.277, 0.340)	(0.384, 0.248)	(0.351, 0.261)	(0.451, 0.187)	(0.272, 0.356)	(0.505, 0.134)
	0.9	(0.221, 0.135)	(0.163, 0.195)	(0.089, 0.257)	(0.284, 0.075)	(0.156, 0.185)	(0.216, 0.137)	(0.197, 0.140)	(0.254, 0.105)	(0.153, 0.197)	(0.284, 0.075)
C5	0.1	(0.235, 0.121)	(0.081, 0.271)	(0.137, 0.187)	(0.148, 0.210)	(0.253, 0.105)	(0.129, 0.225)	(0.157, 0.157)	(0, 0.260)	(0.284, 0.075)	(0.224, 0.124)
	0.2	(0.418, 0.218)	(0.144, 0.484)	(0.243, 0.349)	(0.263, 0.374)	(0.451, 0.188)	(0.230, 0.403)	(0.280, 0.300)	(0, 0.474)	(0.505, 0.134)	(0.399, 0.227)
	0.3	(0.548, 0.288)	(0.189, 0.641)	(0.319, 0.483)	(0.346, 0.492)	(0.592, 0.247)	(0.302, 0.532)	(0.367, 0.425)	(0, 0.649)	(0.662, 0.176)	(0.523, 0.307)
	0.4	(0.627, 0.331)	(0.216, 0.739)	(0.365, 0.580)	(0.395, 0.563)	(0.676, 0.283)	(0.346, 0.612)	(0.420, 0.522)	(0, 0.800)	(0.757, 0.202)	(0.598, 0.358)
	0.5	(0.653, 0.346)	(0.225, 0.774)	(0.380, 0.619)	(0.412, 0.587)	(0.704, 0.295)	(0.360, 0.639)	(0.437, 0.562)	(0, 1)	(0.789, 0.210)	(0.623, 0.376)
	0.6	(0.627, 0.331)	(0.216, 0.739)	(0.365, 0.580)	(0.395, 0.563)	(0.676, 0.283)	(0.346, 0.612)	(0.420, 0.522)	(0, 0.800)	(0.757, 0.202)	(0.598, 0.358)
	0.7	(0.548, 0.288)	(0.189, 0.641)	(0.319, 0.483)	(0.346, 0.492)	(0.592, 0.247)	(0.302, 0.532)	(0.367, 0.425)	(0, 0.649)	(0.662, 0.176)	(0.523, 0.307)
	0.8	(0.418, 0.218)	(0.144, 0.484)	(0.243, 0.349)	(0.263, 0.374)	(0.451, 0.188)	(0.230, 0.403)	(0.280, 0.300)	(0, 0.474)	(0.505, 0.134)	(0.399, 0.227)
	0.9	(0.235, 0.121)	(0.081, 0.271)	(0.137, 0.187)	(0.148, 0.210)	(0.253, 0.105)	(0.129, 0.225)	(0.157, 0.157)	(0, 0.260)	(0.284, 0.075)	(0.224, 0.124)

Table 13: Weighted Aggregated CINFU Decision Matrix for τ Values

	τ	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
	0.1	(0.023, 0.752)	(0.048, 0.645)	(0.046, 0.672)	(0, 0.737)	(0.052, 0.655)	(0.052, 0.655)	(0.063, 0.599)	(0.050, 0.657)	(0.017, 0.755)	(0.023, 0.752)
	0.2	(0.043, 0.845)	(0.093, 0.735)	(0.090, 0.758)	(0, 0.836)	(0.103, 0.736)	(0.103, 0.736)	(0.128, 0.674)	(0.097, 0.741)	(0.031, 0.853)	(0.043, 0.845)
	0.3	(0.059, 0.893)	(0.132, 0.788)	(0.127, 0.804)	(0, 0.896)	(0.148, 0.778)	(0.148, 0.778)	(0.189, 0.714)	(0.139, 0.787)	(0.042, 0.907)	(0.059, 0.893)
	0.4	(0.069, 0.919)	(0.159, 0.819)	(0.153, 0.828)	(0, 0.943)	(0.180, 0.800)	(0.180, 0.800)	(0.238, 0.735)	(0.168, 0.812)	(0.048, 0.938)	(0.069, 0.919)
C1	0.5	(0.072, 0.927)	(0.169, 0.830)	(0.163, 0.836)	(0, 1)	(0.192, 0.807)	(0.192, 0.807)	(0.258, 0.741)	(0.179, 0.820)	(0.050, 0.949)	(0.072, 0.927)
	0.6	(0.069, 0.919)	(0.159, 0.819)	(0.153, 0.828)	(0, 0.943)	(0.180, 0.800)	(0.180, 0.800)	(0.238, 0.735)	(0.168, 0.812)	(0.048, 0.938)	(0.069, 0.919)
	0.7	(0.059, 0.893)	(0.132, 0.788)	(0.127, 0.804)	(0, 0.896)	(0.148, 0.778)	(0.148, 0.778)	(0.189, 0.714)	(0.139, 0.787)	(0.042, 0.907)	(0.059, 0.893)
	0.8	(0.043, 0.845)	(0.093, 0.735)	(0.090, 0.758)	(0, 0.836)	(0.103, 0.736)	(0.103, 0.736)	(0.128, 0.674)	(0.097, 0.741)	(0.031, 0.853)	(0.043, 0.845)
	0.9	(0.023, 0.752)	(0.048, 0.645)	(0.046, 0.672)	(0, 0.737)	(0.052, 0.655)	(0.052, 0.655)	(0.063, 0.599)	(0.050, 0.657)	(0.017, 0.755)	(0.023, 0.752)
	0.1	(0, 0.805)	(0.060, 0.611)	(0.048, 0.662)	(0.019, 0.766)	(0.028, 0.752)	(0.022, 0.762)	(0.037, 0.709)	(0.027, 0.753)	(0.056, 0.636)	(0, 0.805)
	0.2	(0, 0.893)	(0.124, 0.676)	(0.097, 0.739)	(0.036, 0.854)	(0.054, 0.833)	(0.042, 0.847)	(0.073, 0.790)	(0.052, 0.836)	(0.114, 0.705)	(0, 0.893)
	0.3	(0, 0.942)	(0.189, 0.709)	(0.141, 0.782)	(0.049, 0.902)	(0.075, 0.876)	(0.057, 0.893)	(0.102, 0.835)	(0.071, 0.880)	(0.171, 0.741)	(0, 0.942)
	0.4	(0, 0.972)	(0.244, 0.726)	(0.173, 0.806)	(0.057, 0.929)	(0.088, 0.899)	(0.067, 0.920)	(0.122, 0.861)	(0.084, 0.903)	(0.216, 0.759)	(0, 0.972)
C2	0.5	(0, 1)	(0.267, 0.732)	(0.185, 0.814)	(0.060, 0.939)	(0.093, 0.906)	(0.070, 0.929)	(0.130, 0.869)	(0.088, 0.911)	(0.234, 0.765)	(0, 1)
	0.6	(0, 0.972)	(0.244, 0.726)	(0.173, 0.806)	(0.057, 0.929)	(0.088, 0.899)	(0.067, 0.920)	(0.122, 0.861)	(0.084, 0.903)	(0.216, 0.759)	(0, 0.972)
	0.7	(0, 0.942)	(0.189, 0.709)	(0.141, 0.782)	(0.049, 0.902)	(0.075, 0.876)	(0.057, 0.893)	(0.102, 0.835)	(0.071, 0.880)	(0.171, 0.741)	(0, 0.942)
	0.8	(0, 0.893)	(0.124, 0.676)	(0.097, 0.739)	(0.036, 0.854)	(0.054, 0.833)	(0.042, 0.847)	(0.073, 0.790)	(0.052, 0.836)	(0.114, 0.705)	(0, 0.893)
	0.9	(0, 0.805)	(0.060, 0.611)	(0.048, 0.662)	(0.019, 0.766)	(0.028, 0.752)	(0.022, 0.762)	(0.037, 0.709)	(0.027, 0.753)	(0.056, 0.636)	(0, 0.805)
	0.1	(0.052, 0.652)	(0.041, 0.684)	(0.038, 0.706)	(0.052, 0.652)	(0.017, 0.767)	(0.021, 0.743)	(0.032, 0.728)	(0.065, 0.592)	(0.047, 0.669)	(0.052, 0.652)
	0.2	(0.102, 0.735)	(0.079, 0.774)	(0.073, 0.795)	(0.103, 0.734)	(0.031, 0.863)	(0.039, 0.840)	(0.060, 0.819)	(0.132, 0.665)	(0.092, 0.755)	(0.102, 0.735)
	0.3	(0.147, 0.779)	(0.110, 0.824)	(0.101, 0.841)	(0.148, 0.777)	(0.042, 0.913)	(0.053, 0.894)	(0.082, 0.866)	(0.197, 0.703)	(0.130, 0.801)	(0.147, 0.779)
	0.4	(0.179, 0.801)	(0.131, 0.851)	(0.120, 0.864)	(0.181, 0.799)	(0.048, 0.940)	(0.062, 0.924)	(0.097, 0.890)	(0.249, 0.723)	(0.156, 0.825)	(0.179, 0.801)
C3	0.5	(0.191, 0.808)	(0.138, 0.861)	(0.127, 0.872)	(0.193, 0.806)	(0.050, 0.949)	(0.065, 0.934)	(0.102, 0.897)	(0.270, 0.729)	(0.166, 0.833)	(0.191, 0.808)
	0.6	(0.179, 0.801)	(0.131, 0.851)	(0.120, 0.864)	(0.181, 0.799)	(0.048, 0.940)	(0.062, 0.924)	(0.097, 0.890)	(0.249, 0.723)	(0.156, 0.825)	(0.179, 0.801)
	0.7	(0.147, 0.779)	(0.110, 0.824)	(0.101, 0.841)	(0.148, 0.777)	(0.042, 0.913)	(0.053, 0.894)	(0.082, 0.866)	(0.197, 0.703)	(0.130, 0.801)	(0.147, 0.779)
	0.8	(0.102, 0.735)	(0.079, 0.774)	(0.073, 0.795)	(0.103, 0.734)	(0.031, 0.863)	(0.039, 0.840)	(0.060, 0.819)	(0.132, 0.665)	(0.092, 0.755)	(0.102, 0.735)
	0.9	(0.052, 0.652)	(0.041, 0.684)	(0.038, 0.706)	(0.052, 0.652)	(0.017, 0.767)	(0.021, 0.743)	(0.032, 0.728)	(0.065, 0.592)	(0.047, 0.669)	(0.052, 0.652)
	0.1	(0.055, 0.634)	(0.039, 0.689)	(0.021, 0.734)	(0.073, 0.555)	(0.037, 0.681)	(0.054, 0.636)	(0.048, 0.639)	(0.064, 0.598)	(0.037, 0.691)	(0.055, 0.634)
	0.2	(0.107, 0.724)	(0.075, 0.786)	(0.038, 0.838)	(0.147, 0.633)	(0.071, 0.782)	(0.104, 0.728)	(0.093, 0.736)	(0.127, 0.682)	(0.069, 0.790)	(0.107, 0.724)
	0.3	(0.153, 0.771)	(0.103, 0.836)	(0.052, 0.895)	(0.219, 0.674)	(0.098, 0.838)	(0.147, 0.777)	(0.131, 0.792)	(0.185, 0.726)	(0.095, 0.843)	(0.153, 0.771)
	0.4	(0.184, 0.796)	(0.122, 0.862)	(0.060, 0.926)	(0.275, 0.695)	(0.115, 0.868)	(0.178, 0.803)	(0.156, 0.823)	(0.227, 0.749)	(0.112, 0.872)	(0.184, 0.796)
C4	0.5	(0.196, 0.803)	(0.128, 0.871)	(0.063, 0.936)	(0.298, 0.701)	(0.121, 0.878)	(0.188, 0.811)	(0.165, 0.834)	(0.243, 0.756)	(0.118, 0.881)	(0.196, 0.803)
	0.6	(0.184, 0.796)	(0.122, 0.862)	(0.060, 0.926)	(0.275, 0.695)	(0.115, 0.868)	(0.178, 0.803)	(0.156, 0.823)	(0.227, 0.749)	(0.112, 0.872)	(0.184, 0.796)
	0.7	(0.153, 0.771)	(0.103, 0.836)	(0.052, 0.895)	(0.219, 0.674)	(0.098, 0.838)	(0.147, 0.777)	(0.131, 0.792)	(0.185, 0.726)	(0.095, 0.843)	(0.153, 0.771)
	0.8	(0.107, 0.724)	(0.075, 0.786)	(0.038, 0.838)	(0.147, 0.633)	(0.071, 0.782)	(0.104, 0.728)	(0.093, 0.736)	(0.127, 0.682)	(0.069, 0.790)	(0.107, 0.724)
	0.9	(0.055, 0.634)	(0.039, 0.689)	(0.021, 0.734)	(0.073, 0.555)	(0.037, 0.681)	(0.054, 0.636)	(0.048, 0.639)	(0.064, 0.598)	(0.037, 0.691)	(0.055, 0.634)
	0.1	(0.050, 0.663)	(0.016, 0.775)	(0.028, 0.721)	(0.030, 0.738)	(0.055, 0.645)	(0.026, 0.748)	(0.032, 0.697)	(0, 0.769)	(0.063, 0.604)	(0.050, 0.663)
	0.2	(0.100, 0.743)	(0.029, 0.868)	(0.052, 0.814)	(0.057, 0.826)	(0.110, 0.722)	(0.049, 0.838)	(0.061, 0.791)	(0, 0.864)	(0.127, 0.676)	(0.100, 0.743)
	0.3	(0.143, 0.785)	(0.040, 0.917)	(0.072, 0.867)	(0.079, 0.871)	(0.160, 0.761)	(0.067, 0.884)	(0.085, 0.846)	(0, 0.919)	(0.190, 0.713)	(0.143, 0.785)
	0.4	(0.174, 0.806)	(0.046, 0.942)	(0.084, 0.899)	(0.093, 0.894)	(0.197, 0.782)	(0.079, 0.908)	(0.100, 0.881)	(0, 0.957)	(0.241, 0.732)	(0.174, 0.806)
C5	0.5	(0.186, 0.813)	(0.048, 0.951)	(0.089, 0.910)	(0.098, 0.901)	(0.211, 0.788)	(0.083, 0.916)	(0.106, 0.893)	(0, 1)	(0.261, 0.738)	(0.186, 0.813)
	0.6	(0.174, 0.806)	(0.046, 0.942)	(0.084, 0.899)	(0.093, 0.894)	(0.197, 0.782)	(0.079, 0.908)	(0.100, 0.881)	(0, 0.957)	(0.241, 0.732)	(0.174, 0.806)
	0.7	(0.143, 0.785)	(0.040, 0.917)	(0.072, 0.867)	(0.079, 0.871)	(0.160, 0.761)	(0.067, 0.884)	(0.085, 0.846)	(0, 0.919)	(0.190, 0.713)	(0.143, 0.785)
	0.8	(0.100, 0.743)	(0.029, 0.868)	(0.052, 0.814)	(0.057, 0.826)	(0.110, 0.722)	(0.049, 0.838)	(0.061, 0.791)	(0, 0.864)	(0.127, 0.676)	(0.100, 0.743)
	0.9	(0.050, 0.663)	(0.016, 0.775)	(0.028, 0.721)	(0.030, 0.738)	(0.055, 0.645)	(0.026, 0.748)	(0.032, 0.697)	(0, 0.769)	(0.063, 0.604)	(0.050, 0.663)

Table 14: Separation Measures

	$\Delta_{i,r}^{*}$										$\Delta_{i,r}^{-}$									
τ	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**
0.1	0.772	0.750	0.752	0.781	0.761	0.775	0.754	0.763	0.743	0.768	0.404	0.427	0.434	0.385	0.419	0.401	0.416	0.404	0.432	0.390
0.2	0.788	0.760	0.764	0.801	0.773	0.793	0.764	0.776	0.748	0.782	0.389	0.417	0.430	0.359	0.411	0.386	0.402	0.384	0.424	0.364
0.3	0.795	0.762	0.768	0.813	0.776	0.802	0.766	0.780	0.746	0.788	0.383	0.416	0.433	0.343	0.412	0.380	0.399	0.375	0.425	0.349
0.4	0.798	0.760	0.768	0.821	0.776	0.806	0.766	0.782	0.742	0.791	0.380	0.418	0.437	0.333	0.414	0.377	0.399	0.371	0.429	0.340
0.5	0.801	0.760	0.769	0.828	0.776	0.808	0.766	0.786	0.740	0.792	0.380	0.419	0.438	0.329	0.415	0.377	0.400	0.370	0.431	0.336
0.6	0.798	0.760	0.768	0.821	0.776	0.806	0.766	0.782	0.742	0.791	0.380	0.418	0.437	0.333	0.414	0.377	0.399	0.371	0.429	0.340
0.7	0.795	0.762	0.768	0.813	0.776	0.802	0.766	0.780	0.746	0.788	0.383	0.416	0.433	0.343	0.412	0.380	0.399	0.375	0.425	0.349
0.8	0.788	0.760	0.764	0.801	0.773	0.793	0.764	0.776	0.748	0.782	0.389	0.417	0.430	0.359	0.411	0.386	0.402	0.384	0.424	0.364
0.9	0.772	0.750	0.752	0.781	0.761	0.775	0.754	0.763	0.743	0.768	0.404	0.427	0.434	0.385	0.419	0.401	0.416	0.404	0.432	0.390

Source: Author's own elaboration

Step 7. The independent decision matrixes of each DM are aggregated into a single decision matrix using the CINFUWG operator in Equation (7). Table 12 displays the aggregated CINFU decision matrix of alternatives with criteria for τ values that vary from 0 to 1 with a 0.1 increment.

Step 8. Table 13 displays the CINFU weighted decision matrix for τ values, generated using Equation (5) based on Tables 11 and 12.

Step 9. CINFU-PIS and CINFU-NIS are calculated using Equations (15) and (16), respectively.

Step 10: Table 14 displays the separation measures of each option from CINFU-PIS and CINFU-NIS, computed for each τ vale using Equations (17) and (18) based on Table 13.

Step 11: By using the Table 14, the relative closeness coefficients to the ideal solutions with respect to τ value of each alternative is presented in Table 15.

Step 12. Table 16 shows the ranking of alternatives based on final scores for τ values. The best alternative(s) for τ values are chosen in descending order or based on final scores.

Table 16 shows that for all τ values, the 9th Hotel emerges as the best alternative, similarly the last alternative is calculated as the 4th alternative.

Table 16: Relative proximity of alternative τ values

	$\Upsilon_{i,\tau}$									
τ	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**
0.1	7	3	2	10	5	8	4	6	1	9
0.2	7	3	2	10	4	8	5	6	1	9
0.3	6	3	2	10	4	8	5	7	1	9
0.4	6	3	2	10	4	8	5	7	1	9
0.5	6	3	2	10	4	8	5	7	1	9
0.6	6	3	2	10	4	8	5	7	1	9
0.7	6	3	2	10	4	8	5	7	1	9
0.8	7	3	2	10	4	8	5	6	1	9
0.9	7	3	2	10	5	8	4	6	1	9

Source: Author's own elaboration

5. Conclusion

In conclusion, this study presents a novel methodology for strategically selecting the best hotel alternative for the Hotel Airlines Alliance in Türkiye by integrating the SWARA and TOPSIS methods into the Continuous Intuitionistic Fuzzy Sets (CINFUSs) environment. The CINFUSs introduced in Alkan and Kahraman's (2023) study contribute significantly to decision-makers ability to express their ideas more naturally in a continuous range. CINFUSs possess the unique capability to convey information flexibly and continuously, making them particularly powerful for handling problems in uncertain and ambiguous environments. This accuracy in expressing uncertainty contributes to a more precise management of the decision-making process.

The evaluation of 10 hotel alternatives was conducted using five criteria: Scale and scope possibility, Brand value, Tourism attraction, Operating cost, and Industrial

Table 15: Relative similarity of alternatives for τ values

	$\Upsilon_{i,\tau}$									
τ	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**
0.1	0.343	0.363	0.366	0.330	0.354	0.340	0.355	0.346	0.367	0.336
0.2	0.330	0.354	0.360	0.309	0.347	0.327	0.344	0.331	0.361	0.317
0.3	0.325	0.353	0.360	0.297	0.346	0.321	0.342	0.324	0.363	0.307
0.4	0.322	0.354	0.362	0.288	0.348	0.318	0.342	0.321	0.366	0.300
0.5	0.321	0.355	0.363	0.284	0.348	0.318	0.342	0.320	0.368	0.298
0.6	0.322	0.354	0.362	0.288	0.348	0.318	0.342	0.321	0.366	0.300
0.7	0.325	0.353	0.360	0.297	0.346	0.321	0.342	0.324	0.363	0.307
0.8	0.330	0.354	0.360	0.309	0.347	0.327	0.344	0.331	0.361	0.317
0.9	0.343	0.363	0.366	0.330	0.354	0.340	0.355	0.346	0.367	0.336

Source: Author's own elaboration

conditions. Utilizing the CINFUS-SWARA approach, the importance ranking of these criteria was determined as follows: Tourism attraction, Brand value, Industrial conditions, Scale and scope possibility, and Operating cost. These findings align with the results of Fu et al. (2020), providing further validation of the robustness of the integrated methodology.

Moreover, the integration of SWARA and TOPSIS facilitated a comprehensive and systematic decision-making process within the Continuous Intuitionistic Fuzzy Sets environment. SWARA allowed for the determination of criteria weights based on expert opinions, while TOPSIS provided a mathematical model for ranking the alternatives. This study aims to select the best hotel partner for an airline in the HAA concept with the extension of TOPSIS, a traditional MCDM approach that creates a preference ranking by considering the distances of each alternative to the positive and negative solution sets at the same time, and SWARA, a new generation MCDM approach that calculates criteria weights based on the subjective opinions of decision makers, to the CINFUS environment. Although the SWARA approach uses the principle of pairwise comparison in the weight calculation process like the AHP method, which is a traditional MCDM approach, the process steps are less than the AHP method. The integrated use of these two approaches in the CINFUS environment has also made it possible to create a more flexible model for decision makers to reflect their views. In addition to the mentioned advantages, there are some aspects of the study that need to be improved.

Initially, future studies can use the criteria used in this study to calculate the criteria weights with different weight finding methods and make a comparative analysis. Similarly, this study can be repeated using different rangkin methods and comparative analysis can be made with the findings obtained. Scholars continue to introduce new fuzzy sets to the literature. The SWARA-TOPSIS integration in this study can be realized in other fuzzy sets environment and the findings can be compared with the findings of this study. In addition, this study utilizes a subjective weight calculation approach that reflects expert opinions in the model. In other words, the model used directly reaches results in line with expert opinions. In future studies, weights can be calculated for the criteria used in this study with objective criteria weighting methods and a comparative analysis can be performed.

The practical implications of this research are significant for decision-makers in the hospitality industry, particularly for a strategic decision in the scope of HAA. By identifying the most suitable hotel alternative based on multiple criteria, the shareholders can optimize resources, enhance customer satisfaction, and improve their competitive position. Furthermore, the methodology presented in this study contributes to the evolving literature on decision-making methodologies in fuzzy environments, providing a valuable framework for future research in similar contexts. In conclusion, the integration of SWARA-TOPSIS within the Continuous Intuitionistic Fuzzy Sets environment represents a major step forward in decision-making methodologies, and its application in selecting the best hotel alternative for the Hotel Airlines Alliance underscores its efficacy and relevance in real-world scenarios.

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A novel CINFUS-SWARA-TOPSIS methodology for evaluating horizontal Alliances between hotels and airlines

Abstract

This study introduces an innovative approach to strategic decision-making in the hospitality business, with a focus on selecting the best hotel option for the Hotel Airlines Alliance in Türkiye. The incorporation of SWARA (Step-Wise Weight Assessment Ratio Analysis) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) approaches within the Continuous Intuitionistic Fuzzy Sets (CINFUSs) environment is an original effort in decision-making procedures. The evaluation process involved ten hotel alternatives and considered five criteria: Scale and scope possibility, Brand value, Tourism attraction, Operating cost, and Industrial conditions. In the second stage, the subjective criterion weights obtained in the first stage were utilized to rank the 10 hotel alternatives using the CINFUS-TOPSIS approach, with the highest preference potential being prioritized in the first position. The integration of SWARA and TOPSIS facilitated a comprehensive assessment that combined expert opinions (SWARA) for determining criteria weights and mathematical modeling (TOPSIS) for ranking alternatives.

Keywords: *Fuzzy Multiple Criteria Decision Making, Hotel Airlines Alliance, SWARA, TOPSIS.*

Authors

Full Name	Author contribution roles	Contribution rate
Umut Aydın:	*Conceptualism, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision*	*100%*

Author statement: *Author(s) declare(s) that All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.* ***Declaration of Conflicting Interests:*** *The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article*

This paper does not required ethics committee report

Justification: The methodology of this study does not require an ethics committee report.