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# EVALUATION OF TÜRKİYE'S GLACIER TOURISM POTENTIAL WITH MULTI-CRITERIA DECISION-MAKING (MCDM) TECHNIQUES

## Çok Kriterli Karar Verme (ÇKKV) Teknikleriyle Türkiye'nin Buzul Turizmi Potansiyelinin Değerlendirilmesi

**Kuttusi ZORLU*, Volkan DEDE**

**Abstract**

Glacier tourism, a recent trend, has been successfully applied in many glacial areas. Although Türkiye has significant potential regarding these resources, it is still unfamiliar with 'glacier tourism'. The current study evaluates the glacier tourism potential of 12 regions that correspond to the actual glacial areas of Türkiye using CRITIC-ARAS-WASPAS techniques. For this purpose, 18 criteria obtained from the literature were analysed with the help of an expert panel and various secondary data. According to the results, the regions with the most significant potential for glacier tourism development in Türkiye are Rize, Mersin, Hakkâri, Artvin, Kayseri, and Niğde. Various suggestions were presented to the stakeholders for the development and expansion of glacier tourism in these regions. The study and the proposed methodology are expected to make theoretical contributions to the literature as they focus on a topic that has not been addressed before in Türkiye. The results are also anticipated to provide practical knowledge and awareness to local stakeholders in the glacier areas.

**Keywords:** Glacier Tourism, Potential Evaluation, MCDM, CRITIC, ARAS, WASPAS, Türkiye

**Öz**

Son yıllarda popüler olan buzul turizmi birçok buzul bölgesinde başarıyla uygulanmaktadır. Türkiye bu kaynaklar açısından önemli bir potansiyele sahip olmasına rağmen, 'buzul turizmi' konusuna henüz yabancıdır. Mevcut çalışma, Türkiye'nin mevcut buzul alanlarına karşılık gelen 12 yörenin buzul turizmi potansiyelini CRITIC-ARAS-WASPAS yöntemleri ile değerlendirilmeyi amaçlamaktadır. Bu amaçla literatürden elde edilen 18 kriter, uzman paneli ve çeşitli ikincil verilerle değerlendirilerek analiz edilmiştir. Elde edilen bulgulara göre Türkiye'de buzul turizmi açısından en önemli gelişme potansiyeline sahip bölgeler Rize, Mersin, Hakkâri, Artvin, Kayseri ve Niğde'dir. Bu bölgelerde buzul turizminin gelişmesi ve yaygınlaşması için paydaşlara çeşitli öneriler sunulmuştur. Çalışma ve önerilen metodolojinin, Türkiye'de daha önce ele alınmamış bir konuya odaklanması nedeniyle literatüre teorik katkılar sağlayacaktır. Bulguların ayrıca buzul bölgelerindeki yerel paydaşlara pratik bilgi ve farkındalık sağlaması beklenmektedir.

**Anahtar Kelimeler:** Buzul Turizmi, Potansiyel Değerlendirme, ÇKKV, CRITIC, ARAS, WASPAS, Türkiye

* **Corresponding Author:** Dr., Ardahan University, Geography Department, Ardahan, Türkiye., kuttusizorlu@ardahan.edu.tr

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## 1. INTRODUCTION

Glaciers are defined as natural ice masses formed due to the accumulation and metamorphism of snow that has fallen for many years (Turoğlu, 2011). Glaciers, one of the main features of mountainous regions, are mainly known as giant reservoirs of water that constantly exchange mass and energy with the atmosphere, hydrosphere, and other parts of the Earth's systems (Stewart et al., 2016). Additionally, glaciers have been a tourism resource for over 100 years (Yuan & Wang, 2018). The concept of glacier tourism, which emerged at this point, can be defined as the tourism activities carried out in the glacial areas in its most general definition. Various adventure, recreation, and education activities are carried out in glacier holiday centres created in important destinations around the world (Welling et al., 2015). These activities include glacier hiking, ice climbing, scenic helicopter flights, snowmobiling, and glacial lake skiing (Furunes & Mykletun, 2012; Welling et al., 2015; Yuan & Wang, 2018). In addition to the glacier, glacial morphological units (glacial valleys, cirque lakes, glacial rivers, etc.) constitute a supply source for this type of tourism. Regions and countries such as the Scandinavian region, Iceland, the European Alps, the USA, Canada, New Zealand, Argentina, and China are among the world's most important glacier tourism destinations. For example, the Mer de Glace region in France is a developed destination in terms of glacier tourism, and this region hosted a total of 7.7 million visitors in 2019 (Salim et al., 2021a, 2021b). Likewise, the Fox and Franz Josef Glaciers in New Zealand are extensively used for tourism and attract around 500.000 visitors annually (Purdie, 2013). The fact that glacier tourism is developed means that it provides socioeconomic contributions to the regions where they are located. Glacier tourism research in the literature has a history of about 10–15 years. Especially in recent studies, research has been carried out in the context of glaciers and tourism. For example, Welling et al. (2015) discussed glacier tourism studies within the scope of a systematic literature review. Additionally, many studies (e.g., Wang & Zhou, 2019; Wang et al., 2020a; Salim et al., 2021a, 2021b, 2022; Purdie, 2013; Naald, 2020; Purdie et al., 2020; Abrahams et al., 2021; Welling & Abegg, 2021; Stewart et al., 2016) have been focused on the relationship between glacier tourism and global climate change and last chance tourism (LCT). On the Türkiye scale, studies on the sustainable use and management of mountainous areas (Gönençgil, 1999, 2003; Kızılkan, 2021; Koca et al., 2016) and the relationship between mountainous regions and tourism (Kaymaz et al., 2020; Gönençgil & Güngör, 2002; Somuncu, 2003, 2004) have been carried out on such subjects. Despite the studies on mountainous areas in Türkiye, studies on glacier tourism (Zorlu & Dede, 2022) have remained limited. The existence of actual glaciers and paleoglacier traces in Türkiye means (Kurter, 1991) that this type of tourism can be carried out in many areas of Türkiye. Therefore, this study aims to reveal the glacier tourism potential of Türkiye. For this purpose, a methodological approach based on multi-criteria decision-making (MCDM) techniques was designed with various criteria obtained from the literature. Any MCDM technique provides the most appropriate solution to the problems encountered (Stewart, 1992). MCDM techniques allow one to work with a data set of more than one criterion and alternatives to evaluate destination potential. However, studies adopting MCDM approaches in glacier tourism research (Wang et al., 2020b; Sun et al., 2021) are limited. For example, Wang et al. (2020b) evaluated the potential of glacier tourism resources in China according to criteria such as transportation, environmental potential, infrastructure, level of development, and socio-economic conditions. The results show that regions with higher potential indexes include those with better traffic conditions, richer glacial resources, more robust economic and social foundations, closer tourist markets, better accessibility to glacier areas, and richer tourist resources. Based on the above context, using MCDM techniques in this study was deemed appropriate. MCDM techniques such as CRITIC (Criteria Importance Through Inter-criteria Correlation)-ARAS (Additive Ratio Assessment)-WASPAS (Weighted Aggregated Sum Product Assessment) have been used in an integrated manner to evaluate glacier tourism development in Türkiye. In this context, the order of importance of glacier tourism destinations in Türkiye has been determined by weighting the criteria obtained from the literature. The current research results are expected to contribute to the literature in a theoretical sense since glacier tourism is handled empirically in Türkiye. In practical terms, it will inform tourism stakeholders about developing this type of tourism in Türkiye.

## 2. MATERIAL AND METHOD

### 2.1. Actual Glacial Areas of Türkiye

High mountain areas were glaciated during the Late Pleistocene (126–11.7 ka) of the Last Glacial Period on Anatolia, located at mid-latitudes (Çiner & Sarıkaya, 2013). Glaciers reached their largest dimensions, especially at the Last Glacial Maximum (30–20 ka) (Çiner & Sarıkaya, 2013). Glacial areas in Anatolia can be classified as the Eastern Black Sea Mountains, Taurus Mountains, Volcanoes, and independent mountains (Kurter, 1991; Çiner, 2004). The glaciation areas on the Eastern Black Sea Mountains: Karagöl-3036 m a.s.l., Gâvur-3248 m a.s.l., Kaçkar-3932 m a.s.l., Karçal-3431 m a.s.l., Yalnızçam-3167 m a.s.l. can be listed as. Glaciation areas in the Taurus Mountains: Sandıras-2295 m a.s.l., Akdağ-3016 m a.s.l., Dedegöl-2992 m a.s.l., Geyikdağ-2877 m a.s.l., Bolkar-3524 m a.s.l., Aladağlar-3756 m a.s.l., İhtiyar Şahap-3508 m a.s.l., and Buzul-İkiyaka-4168 m a.s.l. Volcanoes and independent mountains: Uludağ-2543 m a.s.l., Erciyes-3917 m a.s.l., Munzur-3463 m a.s.l., Ağrı-5137 m a.s.l., and Süphan-4058 m a.s.l. can be evaluated as There are approximately 30 mountainous masses that underwent glaciation in the Last Glacial Period in Anatolia (Kurter, 1991; Çiner, 2004). Within these mountainous masses, the number of those that contain actual glaciers was 12 (Figure 1, Table 1). For this reason, these 12 areas were selected for the research area.

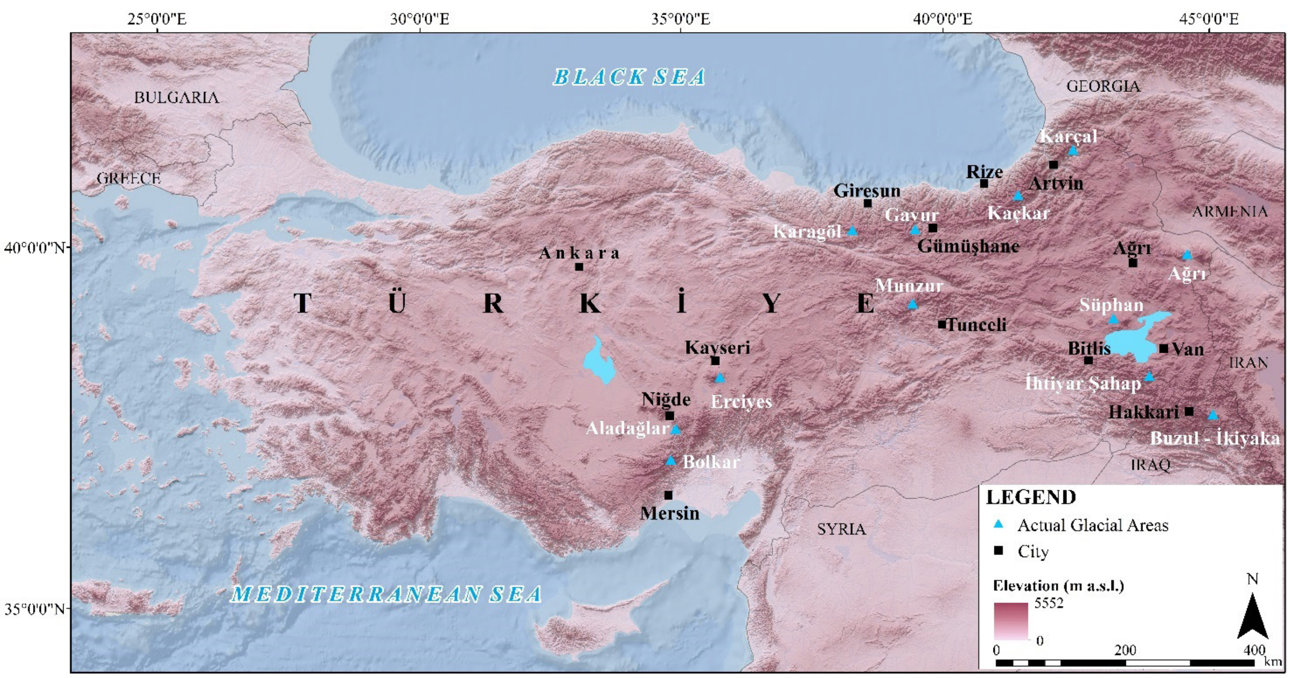


**Figure 1.** Distribution map of actual glaciers in the Anatolian Mountains (Kurter, 1991; Çiner, 2004).

**Table 1.** Elevation and location of the actual glacial areas in the Anatolian Mountains (Bayrakdar & Özdemir, 2010; Çiner, 2003, 2004; Gürgen et al., 2010; Kurter, 1991; Sarıkaya, 2012; Yavaşlı et al., 2015).

| Actual glacial areas | Elevation (m a.s.l.) | Location (City) | Area (km$^2$) | Area (ha) |
|---|---|---|---|---|
| Bolkar | 3524 | Mersin | 1,01 | 101 |
| Aladağlar | 3756 | Niğde | 1,43 | 143 |
| Erciyes | 3917 | Kayseri | 0,002 | 0,2 |
| Karagöl | 3036 | Giresun | 0,04 | 4 |
| Gâvur | 3248 | Gümüşhane | 0,045 | 4,5 |
| Munzur | 3463 | Tunceli | 0,45 | 45 |

| | | | | |
|---|---|---|---|---|
| Kaçkar | 3932 | Rize | 1,91 | 191 |
| Karçal | 3431 | Artvin | 0,78 | 78 |
| Ağrı | 5137 | Ağrı | 5,34 | 534 |
| Süphan | 4058 | Bitlis | 0,31 | 31 |
| İhtiyar Şahap | 3508 | Van | 0,10 | 10 |
| Buzul-İkiyaka | 4168 | Hakkâri | 4,34 | 434 |

Actual glaciers in the Anatolian Mountains may have different characteristics depending on their location. Anatolian mountains with actual glaciers of Bolkarlar (debris-covered glacier), Aladağlar (debris-covered glacier), Erciyes (cirque glacier), Munzur (cirque glacier), Karagöl (cirque glacier), Gâvur (cirque glacier), Kaçkar (cirque glacier), Karçal (cirque glacier), Ağrı (ice cap glacier), Süphan (ice cap glacier), İhtiyar Şahap (cirque glacier), and Buzul (Cilo) (cirque glacier) (Figure 2) (Kurter, 1991; Çiner, 2004; Sarıkaya, 2012; Sarıkaya & Tekeli, 2014; Yavaşlı et al., 2015; Azzoni et al., 2022).


**Figure 2.** Some areas with actual glaciers in Türkiye are a) the Kaçkar Mountains, b) the Karçal Mountains, and c) the Buzul Mountains.

Many studies have been conducted to examine the actual glaciers and paleo glacier traces in Türkiye regarding glacial morphology (Bayrakdar et al., 2015; Dede et al., 2017; Kurter, 1991; Çiner, 2004; Sarıkaya, 2012; Sarıkaya & Tekeli, 2014; Yavaşlı et al., 2015; Azzoni et al., 2022). In addition, studies on glacier tourism in Türkiye (Zorlu & Dede, 2022) are limited in the literature. Examination of glacier tourism in the current research field means that an important gap in the literature will be filled.

## 2.2. Methodological Approach

In this study, the focus is on evaluating Türkiye's glacier tourism potential with CRITIC-ARAS-WASPAS approaches. Wang et al.'s (2020b) 18 criteria used in their studies evaluating the glacier tourism potential in China were adapted to the current research. Urban settlement areas corresponding to Türkiye's actual glaciers were determined as alternatives. Ten of the eighteen criteria (C1, C2, C5, C6, C7, C8, C9, C10, C11, and C13) were evaluated subjectively. Four experts (people with knowledge and experience with glaciers, tourism, and mountainous areas) were selected in the subjective evaluation stage. Assessment indicators scored on a 1-100 scale were included in the criteria (Table 1). For example, the scale used in scoring the indicators belonging to the criteria of "safety of glacial environments" is 1 = very low, 25 = low, 50 = medium, 75 = high, and 100 = very high (Table 2). The remaining eight criteria (C3, C4, C12, C14, C15, C16, C17, and C18) were evaluated using the secondary data of the alternatives. For example, the area of the glacier by destination is added to the decision matrix in hectares.

**Table 2.** Glacier tourism evaluation criteria (adapted from Wang et al., 2020b).

| Subjectively evaluated criteria | Score scale | | | | |
|---|---|---|---|---|---|
| | 1 | 25 | 50 | 75 | 100 |
| **C1** – Accessibility of the glacial scenic area (degree of reaching the glacial areas) | Very difficult | Difficult | Medium | Easy | Very easy |
| **C2** – Accessibility requirements for the glacier area | Accessible with full professional equipment | Accessible with semi-professional equipment | Accessible with medium professional equipment | Accessible with low professional equipment | No professional equipment required |
| **C5** – Integration potential of glaciers and surrounding landscapes (degree of integrated attractiveness status) | Very low | Low | Medium | High | Very high |
| **C6**-Entertainment and tour conditions in the scenic glacier area | Very low | Low | Medium | High | Very high |
| **C7**-The functions of scientific survey, science popularisation, and environmental education | Very low | Low | Medium | High | Very high |
| **C8** – Number of regional tourism resources (other natural and historical sites and parks) | Very low | Low | Medium | High | Very high |
| **C9** – Safety of glacial environments | Very low | Low | Medium | High | Very high |
| **C10** – The current state of glacier tourism development | Very low | Low | Medium | High | Very high |
| **C11** – Glacier use technology and facilities | Very low | Low | Medium | High | Very high |
| **C13** – Regional popularity and influence power | Very low | Low | Medium | High | Very high |

| Criteria evaluated with secondary data | Description/(Unit) | Source |
|---|---|---|
| **C3** – Geographical accessibility of the glacier zone | The distance of the nearest urban settlement to the glacier area is (km). | The measurement from web-based maps |
| **C4** – Typical glacier area | The size of the area covered by the glacier (ha). | Bayrakdar & Özdemir (2010); Çiner (2003); Gürgen et al. (2010); Sarıkaya (2012); Yavaşlı et al. (2015) |
| **C12** – Other tourist facilities | Number of accommodations and social facilities (number). | TURSAB (2020); Ministry of Culture and Tourism (2020) |
| **C14** – Regional GDP | GDP per capita by provinces (Turkish Lira (TL)). | Turkish Statistical Institute (2021) |
| **C15** – Share of the tourism sector in GDP by region | Chained volume index according to economic activity branches of GDP on a provincial basis (TL). | |
| **C16** – Number of arrivals to the facility | The number of visitors coming to the facility on a provincial basis (general/person). | Ministry of Culture and Tourism (2020) |
| **C17** – Number of overnight stays | Number of visitors staying overnight at the facility by province (general)(person). | |
| **C18** – Accommodation facility occupancy rate | The occupancy rate of the facilities based on the province (general) (%) | |

The methodology consisted of three main stages (Figure 3). First, a decision matrix composed of criteria from the literature and alternatives corresponding to the areas with actual glaciers in Türkiye was created. The final matrix was obtained by evaluating the alternatives (subjective and objective) according to the criteria in this matrix. In the next step, the weighting processes of the criteria were carried out using the application steps of CRITIC, an objective weighting technique. ARAS and WASPAS techniques were used to rank the alternatives according to the weighted criteria. In the last stage, the findings of the designs were compared and interpreted. The three methods mentioned are detailed in the following sections.

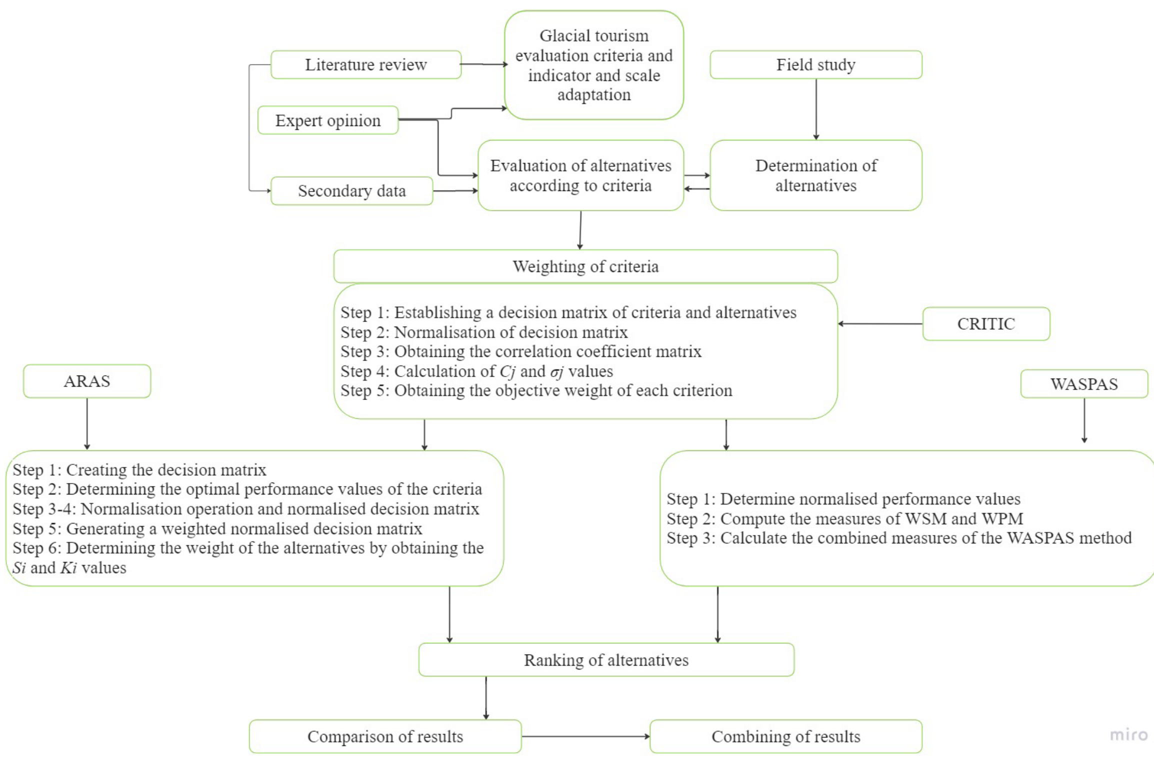


**Figure 3.** The flowchart of the methodological approach.

## 2.3. Criteria Importance through Inter-criteria Correlation (CRITIC) Method

The importance weight of the criteria, which is seen as a source of information in decision-making problems, reflects the amount of information contained in each (Keshavarz Ghorabaee et al., 2017). Therefore, it is necessary to determine the weight of these criteria. The CRITIC technique developed by Diakoulaki et al. (1995) is used to determine the objective weights of the criteria in MCDM problems. In this technique, the objective weighting process includes not only the standard deviation of the criteria, but also the correlation between the criteria and other criteria (Peng et al., 2020; Tuş & Adalı, 2019). The CRITIC technique, besides its objectivity, also includes simple basic calculations (Siksnelyte Butkiene et al., 2020). The CRITIC technique has been successfully applied to obtain objective criterion weights in the literature (Tuş & Adalı, 2019; Zafar et al., 2021; Yalçın & Ünlü, 2018; Peng et al., 2020). Due to the advantages of the technique and the fact that it has been frequently used in the literature, its use was deemed appropriate for weighting the criteria in the current study. The application steps of the CRITIC technique are as follows (Akbulut, 2019; Bulğurcu, 2019; Diakoulaki et al., 1995; Peng et al., 2020; Tuş & Adalı, 2019; Keshavarz Ghorabaee et al., 2017):

Step 1: In the first step, as in other MCDM methods, a decision matrix X, which includes the criteria and alternatives related to the decision problem, is created. Equation (1) is used when creating this matrix.

$$X = [x_{ij}]_{m\times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} (i = 1,2,\dots,m \text{ and } j = 1,2,\dots,n) \quad (1)$$

here, $X_{ij}$ is the preference of the $i^{th}$ alternative with regard to the $j^{th}$ criterion.

Step 2: The decision matrix is normalised. Equation (2) is used for benefit-oriented criteria in the normalisation process, and Equation (3) is used for non-benefit-oriented criteria.

$$x_{ij}^{*} = \frac{x_{ij} - min\ (x_{ij})}{max\ (x_{ij}) - min\ (x_{ij})}\ i = (1,2,\dots,m)\ and\ j = (1,2,\dots,n) \tag{2}$$

$$x_{ij}^{*} = \frac{max(x_{ij}) - x_{ij}}{max\ (x_{ij}) - min\ (x_{ij})}\ i = (1,2,\dots,m)\ and\ j = (1,2,\dots,n \tag{3}$$

$x_{ij}^{*}$ is the normalised value.

Step 3: Correlations are calculated using Equation (4) to measure the relationship between criteria.

$$\rho_{jk} = \frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)(r_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2 \sum_{i=1}^{m}(r_{ik} - \bar{r}_k)^2}}, (j,k = 1,2,\dots,n) \tag{4}$$

Step 4: Using Equation (5), the $C_j$ value representing the amount of information for each criterion is calculated. In addition, $\sigma_j$ values representing the standard deviation of each criterion are obtained by using Equation (6).

$$C_j = \sigma_j \sum_{k=1}^{n}(1 - t_{jk}), j = 1,2,\dots,n \tag{5}$$

$$\sigma_j = \sqrt{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2 / m} \tag{6}$$

Step 5: The weights of the criteria determined in the last step of the method are calculated with the help of Equation (7).

$$W_j = \frac{C_j}{\sum_{k=1}^{n} C_k} \tag{7}$$

### 2.4. Additive Ratio Assessment (ARAS) Method

The ARAS method is a newly developed MCDM method by Zavadskas & Turskis (2010). This technique uses the concept of optimality to find a ranking (Dahooie et al., 2018; Mishra & Rani, 2021). According to the ARAS method, the utility function used to determine the relative effectiveness of a possible alternative in a project is directly proportional to the relative effects of the weights and values of the criteria (Bahrami et al., 2019; Dahooie et al., 2018). With this method, both the performance of the alternatives and their scores are determined, and the alternative scores are compared with the ideal alternative. ARAS has been used to solve complex problems by adapting it to many study areas because it offers simple application steps. The application steps of the technique are as follows (Yıldırım, 2015; Zavadskas & Turskis, 2010; Karadağ Ak et al., 2022; Balki et al., 2020; Ghenai et al., 2020):

Step 1: A decision matrix *X* is created with Equation (8) to show *m* the number of alternatives and *n* the number of criteria.

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}; i = 0,1,\ldots,m; j = 0,1,\ldots,n \quad (8)$$

Step 2: The optimal performance value of the criteria is determined. If the optimal value of criterion j cannot be defined for decision-makers, then:

$$x_{0j} = max_i x_{ij}, if\ max_i x_{ij} is\ benefit;$$
$$x_{oj} = min_i x_{ij}, if\ min_i x_{ij}\ is\ non - benefit \quad (9)$$

Step 3: The normalisation process is performed. The benefit-oriented criteria are normalised by Equation (10). The normalisation process for non-benefit-oriented criteria is carried out in two steps. In the first step, the performance values are converted to the utility using Equation (11), and in the second step, the normalised value is obtained using Equation (10).

$$\bar{x}_{ij} = x_{ij}^* \Big/ \sum_{i=0}^{m} x_{ij}^* \quad (10)$$

$$x_{ij}^* = \frac{1}{x_{ij}} \quad (11)$$

Step 4: After the normalisation process, Equation (12) is used to obtain the normalised decision matrix $\hat{X}$ .

$$\bar{X} = \begin{bmatrix} \bar{x}_{01} & \cdots & \bar{x}_{0j} & \cdots & \bar{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \bar{x}_{i1} & \cdots & \bar{x}_{ij} & \cdots & \bar{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \bar{x}_{m1} & \cdots & \bar{x}_{mj} & \cdots & \bar{x}_{mn} \end{bmatrix}; i = \overline{0,m}; j = \overline{1,n} \quad (12)$$

Step 5: After obtaining the normalised decision matrix, the $\hat{X}$ weighted normalised decision matrix is created using the criterion weights. The weight values of the criteria must satisfy the condition 0 <$w_j$< 1, and the sum of the weights is limited, as shown in Equation (13).

$$\sum_{j=1}^{n} w_j = 1 \quad (13)$$

$$\hat{X} = \begin{bmatrix} \hat{x}_{01} & \cdots & \hat{x}_{0j} & \cdots & \hat{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{i1} & \cdots & \hat{x}_{ij} & \cdots & \hat{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{m1} & \cdots & \hat{x}_{mj} & \cdots & \hat{x}_{mn} \end{bmatrix}; i = \overline{0,m}; j = \overline{1,n} \quad (14)$$

The normalised weighted values of all criteria are calculated by Equation (15):

$$\hat{x}_{ij} = \bar{x}_{ij}.w_{ij} \quad (15)$$

Step 6: In the last step of the method, the optimality function value is calculated for each alternative, and the evaluation of the alternatives is performed. $S_i$, *i.*, the scores of the alternatives are obtained by using Equation (16) to show the optimality function value of the alternative

$$S_i = \sum_{j=1}^{n} \hat{x}_{ij}, i = \overline{0,m}, \tag{16}$$

Values greater than the calculated $S_i$ values indicate more efficient alternatives. Using equation (17), the $S_i$ values of the alternatives are proportioned to the optimal function value $S_{0,}$ and the $K_i$ values are calculated.

$$K_i = \frac{S_i}{S_0}, i = \overline{0,m}, \tag{17}$$

The relative efficiency of the utility function values of the alternatives can be calculated using the $K_i$ ratios that take values in the range of [0, 1]. In this direction, the alternatives are evaluated by ordering the largest to smallest values.

## 2.5. Weighted Aggregated Sum Product Assessment (WASPAS) Method

The WASPAS method is based on combining WSM (Weighted Sum Model) and WPM (Weighted Product Model) with a coefficient (Zavadskas et al., 2012). The WASPAS technique aims to achieve the highest estimation accuracy by optimising the weighted clustered function when ordering the alternatives (Lashgari et al., 2014). This technique separately weights benefit and cost criteria in a decision problem (Siksnelyte Butkiene et al., 2020). In addition, the calculation steps of the process are simple and short. The application steps of the WASPAS method are as follows (Keshavarz Ghorabaee et al., 2017; Zavadskas et al., 2012; Deveci et al., 2018; Tuş & Adalı, 2019).

Step 1: A decision matrix *(X)* showing the performance of different alternatives according to various criteria is created using Equation (1).

Step 2: The generated decision matrix is normalised. Equations (18) and (19) are used to normalise the benefit and non-benefit criteria.

$$x_{ij}^{*} = \frac{x_{ij}}{max_i(x_{ij})} \quad i = 1,2,\ldots,m \; and \; j = 1,2,\ldots,n \tag{18}$$

$$x_{ij}^{*} = \frac{min_i \, x_{ij}}{x_{ij}} \quad i = 1,2,\ldots,m \; and \; j = 1,2,\ldots,n \tag{19}$$

$x_{ij}^{*}$ *i.* is the normalised performance value of the alternative according to the *j.* criterion.

Step 3: Based on the Weighted Sum Method (WSM) *i.*, the overall relative importance of the alternative is calculated using Equation (20).

$$Q_i^{(1)} = \sum_{j=1}^{n} x_{ij}^{*} w_j \tag{20}$$

Step 4: Based on Weighted Product Method (WPM) *i.*, the overall relative importance of the alternative is calculated using Equation (21).

$$Q_i^{(2)} = \prod_{j=1}^{n} (x_{ij}^*)^{w_j} \tag{21}$$

Step 5: The total relative importance of WSM and WPM for each alternative is combined with the help of Equation (22); Thus, weighted combined final scores *($Q_i$)* for each alternative are obtained.

$$Q_i = \lambda Q_i^{(1)} + (1-\lambda) Q_i^{(2)} \tag{22}$$

where λ lies between 0 and 1.

Finally, the alternatives are ranked according to their *Q* values. The best alternative has the highest Q value. If the λ value is 0, the WASPAS method is converted to WPM; if the value is 1, it is converted to WSM.

## 3. ANALYSIS AND RESULTS

### 3.1. CRITIC-ARAS-WASPAS Application

In this study, the implementation of the methodology occurred in three phases. Eighteen criteria, the first adapted from the literature, and twelve alternatives corresponding to the areas with actual glaciers in Türkiye were evaluated using an expert panel and secondary data. Because of the evaluations, a decision matrix was created using Equation (1) to apply the CRITIC technique (Table 1). Then, the normalisation of the decision matrix was performed with Equations (2) and (3). In the third step, the correlation coefficient matrix was obtained by using Equation (4). In the fourth step, the $c_j$ and $\sigma_j$ values of the criteria were calculated with Equations (5) and (6). In the last step, the criteria's $w_j$ (weight) values were obtained with Equation (7). Since the outputs obtained in the mentioned stages are too many, only the decision matrix and $c_j$, $\sigma_j$, and $w_j$ values are presented in Tables 3-4.

**Table 3.** Decision matrix.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A1** | 50 | 75 | 70 | 101 | 75 | 50 | 75 | 100 | 75 | 25 | 1 | 543 | 50 | 52106 | 14,89 | 1433820 | 2706701 | 67,91 |
| **A2** | 25 | 75 | 50 | 143 | 75 | 50 | 75 | 75 | 75 | 25 | 1 | 29 | 50 | 41201 | 10,58 | 82522 | 119268 | 61,77 |
| **A3** | 25 | 50 | 25 | 0,2 | 100 | 50 | 75 | 75 | 50 | 25 | 1 | 62 | 50 | 53359 | 11,27 | 436595 | 742194 | 80,78 |
| **A4** | 50 | 75 | 50 | 4 | 75 | 25 | 25 | 75 | 75 | 1 | 1 | 82 | 25 | 37246 | 11,67 | 229206 | 354183 | 69,82 |
| **A5** | 50 | 75 | 25 | 4,5 | 75 | 25 | 25 | 25 | 50 | 1 | 1 | 21 | 25 | 37978 | 10,04 | 79893 | 129701 | 52,6 |
| **A6** | 25 | 75 | 60 | 45 | 75 | 25 | 50 | 75 | 25 | 25 | 1 | 9 | 50 | 60256 | 19,11 | 34164 | 45085 | 66,86 |
| **A7** | 50 | 75 | 85 | 191 | 100 | 75 | 75 | 75 | 75 | 50 | 50 | 57 | 75 | 47510 | 10,1 | 183970 | 325870 | 61,3 |
| **A8** | 50 | 75 | 45 | 78 | 100 | 25 | 75 | 75 | 50 | 25 | 1 | 104 | 50 | 62019 | 10,9 | 279850 | 430503 | 65,92 |
| **A9** | 1 | 25 | 120 | 534 | 100 | 50 | 75 | 50 | 25 | 50 | 1 | 44 | 50 | 21357 | 14,77 | 78675 | 132194 | 49,67 |
| **A10** | 75 | 50 | 100 | 31 | 75 | 25 | 50 | 50 | 25 | 25 | 1 | 28 | 25 | 27338 | 15,64 | 148157 | 232459 | 65,88 |
| **A11** | 25 | 50 | 65 | 10 | 100 | 25 | 50 | 75 | 25 | 25 | 1 | 77 | 50 | 22104 | 16,42 | 570275 | 1048767 | 98,43 |
| **A12** | 50 | 50 | 30 | 434 | 75 | 50 | 75 | 25 | 25 | 50 | 1 | 19 | 50 | 35908 | 19,91 | 103931 | 141550 | 91,43 |

**Table 4.** $c_j$, $\sigma_j$ and $w_j$ values of the criteria.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma_j$ | 0,27 | 0,34 | 0,31 | 0,33 | 0,51 | 0,33 | 0,4w0 | 0,30 | 0,45 | 0,34 | 0,29 | 0,27 | 0,29 | 0,34 | 0,36 | 0,28 | 0,28 | 0,30 |
| $C_j$ | 4,68 | 5,42 | 5,55 | 5,70 | 8,25 | 4,38 | 5,11 | 4,08 | 6,59 | 4,91 | 4,19 | 3,64 | 3,56 | 4,87 | 6,47 | 3,70 | 3,72 | 4,77 |
| $w_j$ | 0,052 | 0,060 | 0,062 | 0,064 | 0,092 | 0,049 | 0,057 | 0,046 | 0,074 | 0,055 | 0,047 | 0,041 | 0,040 | 0,054 | 0,072 | 0,041 | 0,042 | 0,053 |

In the second stage of the methodological approach, alternatives were prioritized according to weighted criteria using the ARAS technique's application steps. First, an $X$ decision matrix consisting of alternatives and criteria was created with Equation (8), and the optimal performance values of the criteria were determined with Equation (9). Secondly, C3, the non-benefit-oriented criterion, is transformed into a benefit status by Equation (11) (Appendix 1). The matrix obtained in the third step was normalised with Equation (10). After the normalisation process, the normalised decision matrix $\bar{X}$ was obtained using Equation (12) (Appendix 2). After the normalised decision matrix was obtained, the criterion weights determined by the CRITIC technique and Equation (14) were used to create the $\hat{X}$ weighted normalised decision matrix (Appendix 3). $S_i$ values were calculated using Equation (16) in the last step. The degree $K_i$ was calculated by proportioning the obtained $S_i$ values to the optimal function value of $S_0$ with Equation (17). The obtained values are presented in Table 5. According to the table, the city with the most significant potential for glacier tourism was Rize ($K_i$ = 0,689054), while the least was Gümüşhane ($K_i$ = 0,329652).

**Table 5.** The ARAS technique results and ranking of alternatives.

| | $S_i$ | $K_i$ | Rank |
|---|---|---|---|
| **A1 – Mersin** | 0,1126 | 0,675433 | **2** |
| **A2 – Niğde** | 0,0720 | 0,431696 | **7** |
| **A3 – Kayseri** | 0,0781 | 0,468235 | **4** |
| **A4 – Giresun** | 0,0614 | 0,368300 | **9** |
| **A5 – Gümüşhane** | 0,0550 | 0,329652 | **12** |
| **A6 – Tunceli** | 0,0606 | 0,363176 | **10** |
| **A7 – Rize** | 0,1149 | 0,689054 | **1** |
| **A8 – Artvin** | 0,0770 | 0,461787 | **5** |
| **A9 – Ağrı** | 0,0762 | 0,456703 | **6** |
| **A10 – Bitlis** | 0,0573 | 0,343488 | **11** |
| **A11 – Van** | 0,0682 | 0,409213 | **8** |
| **A12 – Hakkâri** | 0,0879 | 0,526874 | **3** |

Finally, the WASPAS technique was used as a second technique to determine the alternatives' priority. This technique starts with a decision matrix consisting of criteria and alternatives, as in Table 3, using Equation (1). The matrix in question is not given at this stage, as it is the same as the matrix in the CRITIC and ARAS methods. The decision matrix created was normalised with the help of Equations (18) and (19). The criteria weights obtained by this matrix and the CRITIC method are presented in Appendix 4. Based on WSM and WPM i., the total relative importance of the alternative $(Q_i^{(1)}, Q_i^{(2)})$ was calculated using Equations (20) and (21) (Appendix 5-6). WSM $(Q_i^{(1)})$ and WPM $(Q_i^{(2)})$ total relative importance values obtained for each alternative were combined with the help of Equation (22), and weighted combined final scores WSPM $(Q_i)$ for each alternative were obtained (Table 6). The alternative with the highest value in question was Mersin, whereas the lowest alternative was Gümüşhane.

**Table 6.** The WASPAS results and ranking of alternatives.

| | $Q_i^{(1)}$ | $Q_i^{(2)}$ | $Q_i$ | Rank |
|---|---|---|---|---|
| **A1 – Mersin** | 0,7219 | 0,5918 | 0,656874 | **1** |
| **A2 – Niğde** | 0,5614 | 0,3906 | 0,476003 | **5** |
| **A3 – Kayseri** | 0,5994 | 0,3216 | 0,460526 | **6** |
| **A4 – Giresun** | 0,4850 | 0,2741 | 0,379587 | **11** |
| **A5 – Gümüşhane** | 0,4419 | 0,2256 | 0,333746 | **12** |
| **A6 – Tunceli** | 0,5065 | 0,2954 | 0,400947 | **9** |
| **A7 – Rize** | 0,7094 | 0,5895 | 0,649437 | **2** |
| **A8 – Artvin** | 0,5945 | 0,4540 | 0,524238 | **3** |
| **A9 – Ağrı** | 0,5153 | 0,3060 | 0,410686 | **8** |
| **A10 – Bitlis** | 0,4502 | 0,3099 | 0,380098 | **10** |
| **A11 – Van** | 0,5131 | 0,3574 | 0,435275 | **7** |
| **A12 – Hakkâri** | 0,6150 | 0,4230 | 0,518986 | **4** |

## 4. EVALUATION OF RESULTS

This study evaluated Türkiye's glacier tourism potential, and the priority values of 12 destinations were obtained according to two different analyses. It can be seen that there are some differences between these approaches. For example, while A1 ranks first and A7 ranks second in the WASPAS results, the ARAS technique found the opposite result (Table 7). These differences are because the methods used have different computational steps. According to the geometric mean of the results of the ARAS and WASPAS methods, the cities from the highest potential to the lowest are Rize, Mersin, Hakkâri, Artvin, Kayseri, Niğde, Ağrı, Van, Tunceli, Giresun, Bitlis, and Gümüşhane (Table 7, Figure 4).

**Table 7.** Comparison of the results.

| | ARAS | Rank | WASPAS | Rank | G. mean | Final ranking |
|---|---|---|---|---|---|---|
| **A1 – Mersin (Bolkar)** | 0,675433 | 2 | 0,656874 | 1 | 0,666089 | 2 |
| **A2 – Niğde (Aladağlar)** | 0,431696 | 7 | 0,476003 | 5 | 0,453308 | 6 |
| **A3 – Kayseri (Erciyes)** | 0,468235 | 4 | 0,460526 | 6 | 0,464365 | 5 |
| **A4 – Giresun (Karagöl)** | 0,368300 | 9 | 0,379587 | 11 | 0,373901 | 10 |
| **A5 – Gümüşhane (Gâvur)** | 0,329652 | 12 | 0,333746 | 12 | 0,331693 | 12 |
| **A6 – Tunceli (Munzur)** | 0,363176 | 10 | 0,400947 | 9 | 0,381594 | 9 |
| **A7 – Rize (Kaçkar)** | 0,689054 | 1 | 0,649437 | 2 | 0,668952 | 1 |
| **A8 – Artvin (Karçal)** | 0,461787 | 5 | 0,524238 | 3 | 0,492023 | 4 |
| **A9 – Ağrı (Ağrı)** | 0,456703 | 6 | 0,410686 | 8 | 0,433084 | 7 |
| **A10 – Bitlis (Süphan)** | 0,343488 | 11 | 0,380098 | 10 | 0,361330 | 11 |
| **A11 – Van (İhtiyar Şahap)** | 0,409213 | 8 | 0,435275 | 7 | 0,422043 | 8 |
| **A12 – Hakkâri (Buzul and İkiyaka)** | 0,526874 | 3 | 0,518986 | 4 | 0,522915 | 3 |

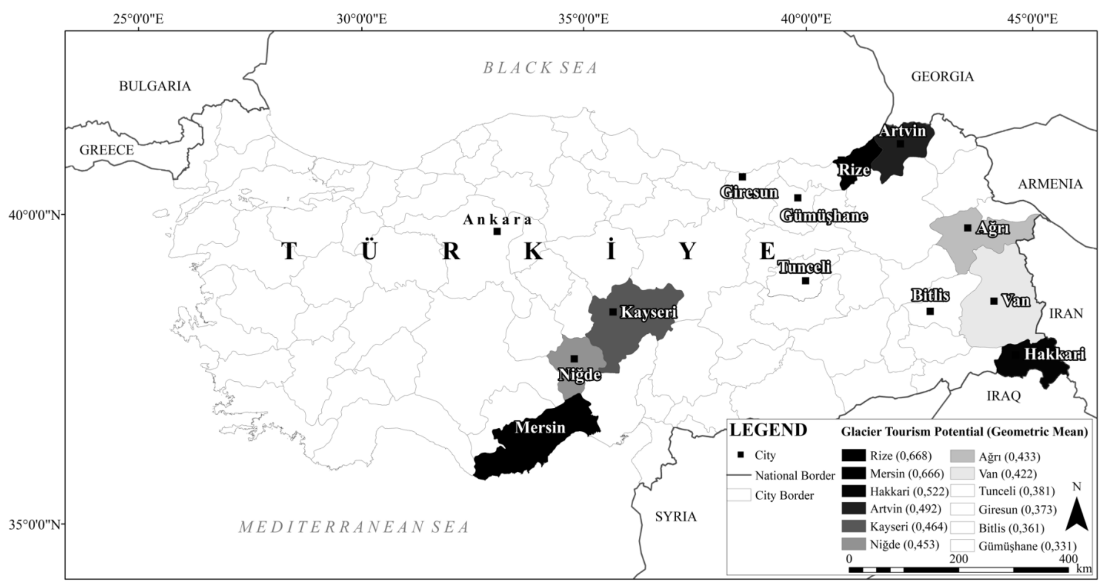


**Figure 4.** Distribution of glacier tourism potential according to analysis results.

Based on the analysis, the six provinces with the highest priority in glacier tourism are Rize, Mersin, Hakkâri, Artvin, Kayseri, and Niğde. The high priority values of these provinces can be attributed to the richness of glacial resources, the developed economic and touristic support capacities, the high image values, the proximity to tourism markets, and the existence of natural-historical-cultural attractions. For example, Rize (Kaçkar Mountains) can be shown among Türkiye's best-known national and international mountain and early glacier tourism destinations (Zaman, 2008). There are two main routes: north (starts from the Upper Kavrun Plateau) and south (it starts from the Yaylalar village), for climbing the Kaçkar Mountain. Visitors use these routes to climb the mountain. Besides this, heliski activities are carried out in the winter (Acuner & Aydın, 2022; Zaman & Birinci, 2009).

On the other hand, Mersin (Bolkar Mountains) is a province with the most crucial touristic infrastructure and transportation opportunities compared to other provinces. It is known that the developed infrastructure in question welcomes visitors with other tourist activities. Mersin, also one of the most developed cities in the country, is the province that hosts the most visitors. The glaciers of the province are the covered glaciers in the Bolkar Mountains. Hakkâri (Buzul and İkiyaka Mountains), one of the study's most interesting results, is among the most underdeveloped provinces of Türkiye regarding socioeconomic characteristics. This region is where transportation infrastructure is the least developed in Türkiye. Simultaneously, although it is in last place in terms of economic-touristic indicators, it has been determined that the region has significant potential for glacier tourism. The biggest reason is that the country has the wealthiest glacial resources. Activities for scientific, educational, and touristic purposes in these glacial areas have become popular. Since the Kayseri and Niğde provinces are located in the Central Anatolian Region of the country, transportation facilities in these provinces are more developed. Additionally, Kayseri is among Türkiye's most developed provinces in the manufacturing sector. Located in Kayseri, Mount Erciyes is one of Türkiye's volcanic mountains with a significant aesthetic value. Mount Erciyes is a frequent destination for professional and semi-professional mountaineering groups. A considerable part of the actual glaciers has receded into this mountainous mass. Likewise, most of the glaciers in Niğde (Aladağlar) have retreated.

The provinces in the last six places in terms of glacier tourism potential are; Ağrı, Tunceli, Van, Bitlis, Giresun, and Gümüşhane. Among these provinces, except for Gümüşhane and Giresun, the others are located in the Eastern Anatolia Region of the country. Most of the country's underdeveloped cities are in this region. Simultaneously, the negative effects of topography and climate in this region are reflected in the inconvenience of transportation. Mount Ağrı, the area with Türkiye's highest and, simultaneously, the largest glacier, has an essential potential for glacier tourism. In Mount Ağrı, glaciers form an integrated potential with other resource attractions. However, it is known that security vulnerabilities have been experienced in this region in the past, as in the Hakkâri and Tunceli regions. This situation is seen as a significant disadvantage. Tunceli (Munzur Mountains) has rich glacial resources and natural touristic offerings that can be integrated into these resources. In this region, which is underdeveloped in socioeconomic terms, there may be a security gap from time to time. Van (İhtiyar Şahap Mountains) is among the most developed cities in its region. With this advantage and its rich natural, historical, and cultural resources, it can be brought to the fore with glacier tourism activities in Türkiye. The low socioeconomic support capacities in Bitlis (Süphan), Giresun (Karagöl), and Gümüşhane (Gâvur) have resulted in a low glacier tourism potential.

### 4.1. Theoretical and Practical Implications

As in all scientific studies, this study is thought to make various theoretical and practical contributions. There are some implications for the study from a theoretical perspective. First, no research has been found empirically examining the potential of 'glacier tourism in any destination in Türkiye. Therefore, this study is the first and most comprehensive attempt to address the issue of glacier tourism in Türkiye. Results will make the current study more visible by deepening the field-specific subject literature. Second, this study evidenced the applicability of MCDM techniques in assessing glacier tourism destination potential. Choosing the most suitable one among more than one alternative using various criteria is an MCDM problem. It has been seen that it would be appropriate to use these techniques, especially in tourism potential evaluation studies. Finally, the methodology used in the study can be adapted to different spatial scales for different types of tourism. Therefore, the research results will provide essential information for future studies.

In practical terms, it is anticipated that the research will provide various implications for the tourism industry in Türkiye and the world, as well as for destination management companies and marketers. First, national and local stakeholders (such as tourism investors-entrepreneurs, tourism planners, policymakers, and residents) lack knowledge and awareness about glacier tourism in Türkiye. The results are expected to provide stakeholders with insights into this type of tourism. Secondly, promoting these destinations effectively and accurately in the national and international arena and establishing brand and image values are necessary. Different content (photos, videos, blogs, etc.) can be shared and disseminated via social media. Finally, stakeholders should focus on accessibility, tourist facilities, and safety to develop glacier tourism in destinations with existing glaciers in Türkiye. In particular, glacier tourism points can be established with up-to-date and sustainable tourism planning by closely following the important glacier tourism destinations in the world (such as France-Montenvers and Aiguille du Midi; China-Sichuan Dagu glacier; Australia-Fox and Franz Josef glaciers). Various alternative transportation technologies (cable cars, elevators, chairlifts, etc.) can be used to make accessibility easier. By conducting sensitive area levelling studies in glacial regions, transportation technologies can be developed up to places where human activities are intense. Again, the research results will guide the stakeholders in this regard.

### 4.2. Limitations and Suggestions for Future Research

The current research has some limitations, and future studies should take these limitations into account. First, both objective (various physical characteristics, touristic, economic indicators, etc.) and subjective (expert evaluation) data were used in the application phase of the MCDM techniques used in the research. This situation slightly overshadowed the objectivity of the study. To prevent this situation in future research, integrating MCDM techniques with fuzzy set theories (fuzzy, type-2, intuitionistic, spherical, etc.) will minimise the problem of objectivity. In addition, the data obtained through expert evaluation only reflect the opinions of selected experts on the subject. Second, the methodology used in the research can be adapted to different types of tourism at different geographical scales, and the results can be interpreted by comparing the results of the current study. Finally, future researchers can focus on issues such as the relationship between glacier tourism and climate change, visitor perceptions, and visitor attitudes to help the glacier tourism literature develop further in Türkiye.

## 5. CONCLUSION

The current study evaluates Türkiye's glacier tourism potential using various criteria and CRITIC-ARAS-WASPAS techniques. Because of the analysis, the prominence of some provinces in glacier tourism can be explained by their socioeconomic development (such as Mersin and Kayseri) and their glacial resources (such as Rize, Artvin, Hakkâri, Ağrı). The transportation factor was also ineffective, even in the most unfavourable region (Hakkâri). It has been determined that the potential of the areas (such as Giresun and Gümüşhane) where most glaciers have withdrawn is low. However, these regions' low socioeconomic development levels also influenced this situation. Stakeholders should study and improve areas with high potential for developing glacier tourism in Türkiye. First, the concept of 'glacier tourism' should be brought to the fore in the national and international arenas, and an image should be created. This is especially necessary to compete with the well-known glacier tourism destinations in the world (France, Italy, USA, New Zealand, China, etc.). Currently, few agencies offer a tour package or organisation within the scope of glacier tourism in Türkiye. These companies organise tours for the glacial regions in Kaçkar, Munzur, and Hakkâri. Researchers, explorers, independent groups, and hermits are unofficially engaged in glacier tourism activities. Tour and organisation investments should be increased for glacier tourism, and these regions should be emphasised. Tourism in glacial regions, which are sensitive areas that need to be protected, should be planned from a sustainability perspective. For this, priorities such as creating carrying capacity with various zonings, reducing the carbon footprint, and financing the protection of resources with the income obtained from tourism should be determined. Second, access and accessibility to glacial environments should be made convenient. Transportation is easily provided in the 12 cities under discussion. However, to reach the glacial environments in these cities, it is necessary to develop other transportation technologies (such as cable cars, chairlifts, and gear trains) up to a certain point. For example, these transportation technologies can provide access to plateaus. Third, tourist infrastructure and superstructures should be created in some regions (such as Artvin, Hakkâri, and Tunceli) to develop glacier tourism. Fourth, there are terrorist risks in some mountainous masses rather than natural security risks due to the retreat of glaciers. This security vulnerability should be removed. Finally, as in the rest of the world, the effects of global climate change in Türkiye also threaten the retreat of glaciers (Çiner & Sarıkaya, 2013; Türkeş, 2008) and the sustainability of this type of tourism (Salim et al., 2021b). Thus, climate change negatively affects the visibility, accessibility, safety, and comfort of the glacier landscape in glacier tourism (Welling et al., 2015). Focusing on issues such as the adaptation and sustainability of glacier tourism to climate change is necessary to prevent this situation. In this context, alternatives such as wrapping the glaciers with protective covers (Wang et al., 2010) and making artificial snow (Welling et al., 2015) can be evaluated. In addition, last chance tourism (LCT) can also provide benefits for the sustainable operation of glacier tourism.

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The authors declare no competing interests.

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## Appendix(s)

**Table A1.** Decision matrix where optimum values are determined.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Optim.** | 75 | 75 | 0,04 | 534 | 100 | 75 | 75 | 100 | 75 | 50 | 25 | 543 | 75 | 62019 | 19,91 | 1433820 | 2706701 | 98,43 |
| **A1** | 50 | 75 | 0,0143 | 101 | 75 | 50 | 75 | 100 | 75 | 25 | 1 | 543 | 50 | 52106 | 14,89 | 1433820 | 2706701 | 67,91 |
| **A2** | 25 | 75 | 0,0200 | 143 | 75 | 50 | 75 | 75 | 75 | 25 | 1 | 29 | 50 | 41201 | 10,58 | 82522 | 119268 | 61,77 |
| **A3** | 25 | 50 | 0,0400 | 0,2 | 100 | 50 | 75 | 75 | 50 | 25 | 1 | 62 | 50 | 53359 | 11,27 | 436595 | 742194 | 80,78 |
| **A4** | 50 | 75 | 0,0200 | 4,0 | 75 | 25 | 25 | 75 | 75 | 1 | 1 | 82 | 25 | 37246 | 11,67 | 229206 | 354183 | 69,82 |
| **A5** | 50 | 75 | 0,0400 | 4,5 | 75 | 25 | 25 | 25 | 50 | 1 | 1 | 21 | 25 | 37978 | 10,04 | 79893 | 129701 | 52,60 |
| **A6** | 25 | 75 | 0,0167 | 45 | 75 | 25 | 50 | 50 | 25 | 25 | 1 | 9 | 50 | 60256 | 19,11 | 34164 | 45085 | 66,86 |
| **A7** | 50 | 75 | 0,0118 | 191 | 100 | 75 | 75 | 75 | 75 | 50 | 50 | 57 | 75 | 47510 | 10,10 | 183970 | 325870 | 61,30 |
| **A8** | 50 | 75 | 0,0222 | 78 | 100 | 25 | 75 | 75 | 50 | 25 | 1 | 104 | 50 | 62019 | 10,90 | 279850 | 430503 | 65,92 |
| **A9** | 1 | 25 | 0,0083 | 534 | 100 | 50 | 75 | 50 | 25 | 50 | 1 | 44 | 50 | 21357 | 14,77 | 78675 | 132194 | 49,67 |
| **A10** | 75 | 50 | 0,0100 | 31 | 75 | 25 | 50 | 50 | 25 | 25 | 1 | 28 | 25 | 27338 | 15,64 | 148157 | 232459 | 65,88 |
| **A11** | 25 | 50 | 0,0154 | 10 | 100 | 25 | 50 | 75 | 25 | 25 | 1 | 77 | 50 | 22104 | 16,42 | 570275 | 1048767 | 98,43 |
| **A12** | 50 | 50 | 0,0333 | 434 | 75 | 50 | 75 | 25 | 25 | 50 | 1 | 19 | 50 | 35908 | 19,91 | 103931 | 141550 | 91,43 |
| **Sum** | 501 | 775 | 0,259 | 1676 | 1050 | 500 | 725 | 825 | 625 | 327 | 85 | 1599 | 575 | 524493 | 165,30 | 4990947 | 8973626 | 839,37 |

**Table A2.** Normalised decision matrix.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Optim.** | 0,150 | 0,097 | 0,155 | 0,319 | 0,095 | 0,150 | 0,103 | 0,121 | 0,120 | 0,153 | 0,294 | 0,340 | 0,130 | 0,118 | 0,120 | 0,287 | 0,302 | 0,117 |
| **A1** | 0,100 | 0,097 | 0,055 | 0,060 | 0,071 | 0,100 | 0,103 | 0,121 | 0,120 | 0,076 | 0,012 | 0,340 | 0,087 | 0,099 | 0,090 | 0,287 | 0,302 | 0,081 |
| **A2** | 0,050 | 0,097 | 0,077 | 0,085 | 0,071 | 0,100 | 0,103 | 0,091 | 0,120 | 0,076 | 0,012 | 0,018 | 0,087 | 0,079 | 0,064 | 0,017 | 0,013 | 0,074 |
| **A3** | 0,050 | 0,065 | 0,155 | 0,000 | 0,095 | 0,100 | 0,103 | 0,091 | 0,080 | 0,076 | 0,012 | 0,039 | 0,087 | 0,102 | 0,068 | 0,087 | 0,083 | 0,096 |
| **A4** | 0,100 | 0,097 | 0,077 | 0,002 | 0,071 | 0,050 | 0,034 | 0,091 | 0,120 | 0,003 | 0,012 | 0,051 | 0,043 | 0,071 | 0,071 | 0,046 | 0,039 | 0,083 |
| **A5** | 0,100 | 0,097 | 0,155 | 0,003 | 0,071 | 0,050 | 0,034 | 0,030 | 0,080 | 0,003 | 0,012 | 0,013 | 0,043 | 0,072 | 0,061 | 0,016 | 0,014 | 0,063 |
| **A6** | 0,050 | 0,097 | 0,064 | 0,027 | 0,071 | 0,050 | 0,069 | 0,061 | 0,040 | 0,076 | 0,012 | 0,006 | 0,087 | 0,115 | 0,116 | 0,007 | 0,005 | 0,080 |
| **A7** | 0,100 | 0,097 | 0,045 | 0,114 | 0,095 | 0,150 | 0,103 | 0,091 | 0,120 | 0,153 | 0,588 | 0,036 | 0,130 | 0,091 | 0,061 | 0,037 | 0,036 | 0,073 |
| **A8** | 0,100 | 0,097 | 0,086 | 0,047 | 0,095 | 0,050 | 0,103 | 0,091 | 0,080 | 0,076 | 0,012 | 0,065 | 0,087 | 0,118 | 0,066 | 0,056 | 0,048 | 0,079 |
| **A9** | 0,002 | 0,032 | 0,032 | 0,319 | 0,095 | 0,100 | 0,103 | 0,061 | 0,040 | 0,153 | 0,012 | 0,028 | 0,087 | 0,041 | 0,089 | 0,016 | 0,015 | 0,059 |
| **A10** | 0,150 | 0,065 | 0,039 | 0,018 | 0,071 | 0,050 | 0,069 | 0,061 | 0,040 | 0,076 | 0,012 | 0,018 | 0,043 | 0,052 | 0,095 | 0,030 | 0,026 | 0,078 |
| **A11** | 0,050 | 0,065 | 0,059 | 0,006 | 0,095 | 0,050 | 0,069 | 0,091 | 0,040 | 0,076 | 0,012 | 0,048 | 0,087 | 0,042 | 0,099 | 0,114 | 0,117 | 0,117 |
| **A12** | 0,100 | 0,065 | 0,129 | 0,259 | 0,071 | 0,100 | 0,103 | 0,030 | 0,040 | 0,153 | 0,012 | 0,012 | 0,087 | 0,068 | 0,120 | 0,021 | 0,016 | 0,109 |

**Table A3.** Weighted normalised decision matrix.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight** | 0,052 | 0,060 | 0,062 | 0,064 | 0,092 | 0,049 | 0,057 | 0,046 | 0,074 | 0,055 | 0,047 | 0,041 | 0,040 | 0,054 | 0,072 | 0,041 | 0,042 | 0,053 |
| **Optim.** | 0,008 | 0,006 | 0,010 | 0,020 | 0,009 | 0,007 | 0,006 | 0,006 | 0,009 | 0,008 | 0,014 | 0,014 | 0,005 | 0,006 | 0,009 | 0,012 | 0,013 | 0,006 |
| **A1** | 0,005 | 0,006 | 0,003 | 0,004 | 0,007 | 0,005 | 0,006 | 0,006 | 0,009 | 0,004 | 0,001 | 0,014 | 0,003 | 0,005 | 0,006 | 0,012 | 0,013 | 0,004 |
| **A2** | 0,003 | 0,006 | 0,005 | 0,005 | 0,007 | 0,005 | 0,006 | 0,004 | 0,009 | 0,004 | 0,001 | 0,001 | 0,003 | 0,004 | 0,005 | 0,001 | 0,001 | 0,004 |
| **A3** | 0,003 | 0,004 | 0,010 | 0,000 | 0,009 | 0,005 | 0,006 | 0,004 | 0,006 | 0,004 | 0,001 | 0,002 | 0,003 | 0,006 | 0,005 | 0,004 | 0,003 | 0,005 |
| **A4** | 0,005 | 0,006 | 0,005 | 0,000 | 0,007 | 0,002 | 0,002 | 0,004 | 0,009 | 0,000 | 0,001 | 0,002 | 0,002 | 0,004 | 0,005 | 0,002 | 0,002 | 0,004 |
| **A5** | 0,005 | 0,006 | 0,010 | 0,000 | 0,007 | 0,002 | 0,002 | 0,001 | 0,006 | 0,000 | 0,001 | 0,001 | 0,002 | 0,004 | 0,004 | 0,001 | 0,001 | 0,003 |
| **A6** | 0,003 | 0,006 | 0,004 | 0,002 | 0,007 | 0,002 | 0,004 | 0,003 | 0,003 | 0,004 | 0,001 | 0,000 | 0,003 | 0,006 | 0,008 | 0,000 | 0,000 | 0,004 |
| **A7** | 0,005 | 0,006 | 0,003 | 0,007 | 0,009 | 0,007 | 0,006 | 0,004 | 0,009 | 0,008 | 0,028 | 0,001 | 0,005 | 0,005 | 0,004 | 0,002 | 0,002 | 0,004 |
| **A8** | 0,005 | 0,006 | 0,005 | 0,003 | 0,009 | 0,002 | 0,006 | 0,004 | 0,006 | 0,004 | 0,001 | 0,003 | 0,003 | 0,006 | 0,005 | 0,002 | 0,002 | 0,004 |
| **A9** | 0,000 | 0,002 | 0,002 | 0,020 | 0,009 | 0,005 | 0,006 | 0,003 | 0,003 | 0,008 | 0,001 | 0,001 | 0,003 | 0,002 | 0,006 | 0,001 | 0,001 | 0,003 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A10** | 0,008 | 0,004 | 0,002 | 0,001 | 0,007 | 0,002 | 0,004 | 0,003 | 0,003 | 0,004 | 0,001 | 0,001 | 0,002 | 0,003 | 0,007 | 0,001 | 0,001 | 0,004 |
| **A11** | 0,003 | 0,004 | 0,004 | 0,000 | 0,009 | 0,002 | 0,004 | 0,004 | 0,003 | 0,004 | 0,001 | 0,002 | 0,003 | 0,002 | 0,007 | 0,005 | 0,005 | 0,006 |
| **A12** | 0,005 | 0,004 | 0,008 | 0,016 | 0,007 | 0,005 | 0,006 | 0,001 | 0,003 | 0,008 | 0,001 | 0,000 | 0,003 | 0,004 | 0,009 | 0,001 | 0,001 | 0,006 |

**Table A4.** Normalised matrix and criterion weights.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight** | 0,052 | 0,060 | 0,062 | 0,064 | 0,092 | 0,049 | 0,057 | 0,046 | 0,074 | 0,055 | 0,047 | 0,041 | 0,040 | 0,054 | 0,072 | 0,041 | 0,042 | 0,053 |
| **A1** | 0,667 | 1,000 | 0,357 | 0,189 | 0,750 | 0,667 | 1,000 | 1,000 | 1,000 | 0,500 | 0,020 | 1,000 | 0,667 | 0,840 | 0,748 | 1,000 | 1,000 | 0,690 |
| **A2** | 0,333 | 1,000 | 0,500 | 0,268 | 0,750 | 0,667 | 1,000 | 0,750 | 1,000 | 0,500 | 0,020 | 0,053 | 0,667 | 0,664 | 0,531 | 0,058 | 0,044 | 0,628 |
| **A3** | 0,333 | 0,667 | 1,000 | 0,000 | 1,000 | 0,667 | 1,000 | 0,750 | 0,667 | 0,500 | 0,020 | 0,114 | 0,667 | 0,860 | 0,566 | 0,304 | 0,274 | 0,821 |
| **A4** | 0,667 | 1,000 | 0,500 | 0,007 | 0,750 | 0,333 | 0,333 | 0,750 | 1,000 | 0,020 | 0,020 | 0,151 | 0,333 | 0,601 | 0,586 | 0,160 | 0,131 | 0,709 |
| **A5** | 0,667 | 1,000 | 1,000 | 0,008 | 0,750 | 0,333 | 0,333 | 0,250 | 0,667 | 0,020 | 0,020 | 0,039 | 0,333 | 0,612 | 0,504 | 0,056 | 0,048 | 0,534 |
| **A6** | 0,333 | 1,000 | 0,417 | 0,084 | 0,750 | 0,333 | 0,667 | 0,750 | 0,333 | 0,500 | 0,020 | 0,017 | 0,667 | 0,972 | 0,960 | 0,024 | 0,017 | 0,679 |
| **A7** | 0,667 | 1,000 | 0,294 | 0,358 | 1,000 | 1,000 | 1,000 | 0,750 | 1,000 | 1,000 | 1,000 | 0,105 | 1,000 | 0,766 | 0,507 | 0,128 | 0,120 | 0,623 |
| **A8** | 0,667 | 1,000 | 0,556 | 0,146 | 1,000 | 0,333 | 1,000 | 0,750 | 0,667 | 0,500 | 0,020 | 0,192 | 0,667 | 1,000 | 0,547 | 0,195 | 0,159 | 0,670 |
| **A9** | 0,013 | 0,333 | 0,208 | 1,000 | 1,000 | 0,667 | 1,000 | 0,500 | 0,333 | 1,000 | 0,020 | 0,081 | 0,667 | 0,344 | 0,742 | 0,055 | 0,049 | 0,505 |
| **A10** | 1,000 | 0,667 | 0,250 | 0,058 | 0,750 | 0,333 | 0,667 | 0,500 | 0,333 | 0,500 | 0,020 | 0,052 | 0,333 | 0,441 | 0,786 | 0,103 | 0,086 | 0,669 |
| **A11** | 0,333 | 0,667 | 0,385 | 0,019 | 1,000 | 0,333 | 0,667 | 0,750 | 0,333 | 0,500 | 0,020 | 0,142 | 0,667 | 0,356 | 0,825 | 0,398 | 0,387 | 1,000 |
| **A12** | 0,667 | 0,667 | 0,833 | 0,813 | 0,750 | 0,667 | 1,000 | 0,250 | 0,333 | 1,000 | 0,020 | 0,035 | 0,667 | 0,579 | 1,000 | 0,072 | 0,052 | 0,929 |

**Table A5.** Total relative significance values based on WSM.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | WSM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A1** | 0,035 | 0,060 | 0,022 | 0,012 | 0,069 | 0,033 | 0,057 | 0,046 | 0,074 | 0,027 | 0,001 | 0,041 | 0,026 | 0,046 | 0,054 | 0,041 | 0,042 | 0,037 | 0,722 |
| **A2** | 0,017 | 0,060 | 0,031 | 0,017 | 0,069 | 0,033 | 0,057 | 0,034 | 0,074 | 0,027 | 0,001 | 0,002 | 0,026 | 0,036 | 0,038 | 0,002 | 0,002 | 0,033 | 0,561 |
| **A3** | 0,017 | 0,040 | 0,062 | 0,000 | 0,092 | 0,033 | 0,057 | 0,034 | 0,049 | 0,027 | 0,001 | 0,005 | 0,026 | 0,047 | 0,041 | 0,013 | 0,011 | 0,044 | 0,599 |
| **A4** | 0,035 | 0,060 | 0,031 | 0,000 | 0,069 | 0,016 | 0,019 | 0,034 | 0,074 | 0,001 | 0,001 | 0,006 | 0,013 | 0,033 | 0,042 | 0,007 | 0,005 | 0,038 | 0,485 |
| **A5** | 0,035 | 0,060 | 0,062 | 0,001 | 0,069 | 0,016 | 0,019 | 0,011 | 0,049 | 0,001 | 0,001 | 0,002 | 0,013 | 0,033 | 0,036 | 0,002 | 0,002 | 0,028 | 0,442 |
| **A6** | 0,017 | 0,060 | 0,026 | 0,005 | 0,069 | 0,016 | 0,038 | 0,034 | 0,025 | 0,027 | 0,001 | 0,001 | 0,026 | 0,053 | 0,069 | 0,001 | 0,001 | 0,036 | 0,507 |
| **A7** | 0,035 | 0,060 | 0,018 | 0,023 | 0,092 | 0,049 | 0,057 | 0,034 | 0,074 | 0,055 | 0,047 | 0,004 | 0,040 | 0,042 | 0,037 | 0,005 | 0,005 | 0,033 | 0,709 |
| **A8** | 0,035 | 0,060 | 0,034 | 0,009 | 0,092 | 0,016 | 0,057 | 0,034 | 0,049 | 0,027 | 0,001 | 0,008 | 0,026 | 0,054 | 0,039 | 0,008 | 0,007 | 0,036 | 0,594 |
| **A9** | 0,001 | 0,020 | 0,013 | 0,064 | 0,092 | 0,033 | 0,057 | 0,023 | 0,025 | 0,055 | 0,001 | 0,003 | 0,026 | 0,019 | 0,054 | 0,002 | 0,002 | 0,027 | 0,515 |
| **A10** | 0,052 | 0,040 | 0,015 | 0,004 | 0,069 | 0,016 | 0,038 | 0,023 | 0,025 | 0,027 | 0,001 | 0,002 | 0,013 | 0,024 | 0,057 | 0,004 | 0,004 | 0,036 | 0,450 |
| **A11** | 0,017 | 0,040 | 0,024 | 0,001 | 0,092 | 0,016 | 0,038 | 0,034 | 0,025 | 0,027 | 0,001 | 0,006 | 0,026 | 0,019 | 0,060 | 0,016 | 0,016 | 0,053 | 0,513 |
| **A12** | 0,035 | 0,040 | 0,052 | 0,052 | 0,069 | 0,033 | 0,057 | 0,011 | 0,025 | 0,055 | 0,001 | 0,001 | 0,026 | 0,031 | 0,072 | 0,003 | 0,002 | 0,049 | 0,615 |

**Table A6.** Total relative significance values based on WPM.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | WPM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A1** | 0,979 | 1,000 | 0,938 | 0,900 | 0,974 | 0,980 | 1,000 | 1,000 | 1,000 | 0,963 | 0,833 | 1,000 | 0,984 | 0,991 | 0,979 | 1,000 | 1,000 | 0,980 | 0,592 |
| **A2** | 0,944 | 1,000 | 0,958 | 0,920 | 0,974 | 0,980 | 1,000 | 0,987 | 1,000 | 0,963 | 0,833 | 0,888 | 0,984 | 0,978 | 0,955 | 0,889 | 0,878 | 0,975 | 0,391 |
| **A3** | 0,944 | 0,976 | 1,000 | 0,606 | 1,000 | 0,980 | 1,000 | 0,987 | 0,971 | 0,963 | 0,833 | 0,916 | 0,984 | 0,992 | 0,960 | 0,952 | 0,948 | 0,990 | 0,322 |
| **A4** | 0,979 | 1,000 | 0,958 | 0,733 | 0,974 | 0,948 | 0,939 | 0,987 | 1,000 | 0,807 | 0,833 | 0,926 | 0,957 | 0,973 | 0,962 | 0,927 | 0,919 | 0,982 | 0,274 |
| **A5** | 0,979 | 1,000 | 1,000 | 0,738 | 0,974 | 0,948 | 0,939 | 0,939 | 0,971 | 0,807 | 0,833 | 0,876 | 0,957 | 0,974 | 0,952 | 0,887 | 0,881 | 0,967 | 0,226 |
| **A6** | 0,944 | 1,000 | 0,947 | 0,854 | 0,974 | 0,948 | 0,977 | 0,987 | 0,922 | 0,963 | 0,833 | 0,847 | 0,984 | 0,998 | 0,997 | 0,857 | 0,844 | 0,980 | 0,295 |
| **A7** | 0,979 | 1,000 | 0,927 | 0,937 | 1,000 | 1,000 | 1,000 | 0,987 | 1,000 | 1,000 | 1,000 | 0,913 | 1,000 | 0,986 | 0,952 | 0,919 | 0,916 | 0,975 | 0,590 |
| **A8** | 0,979 | 1,000 | 0,964 | 0,885 | 1,000 | 0,948 | 1,000 | 0,987 | 0,971 | 0,963 | 0,833 | 0,935 | 0,984 | 1,000 | 0,957 | 0,935 | 0,926 | 0,979 | 0,454 |
| **A9** | 0,798 | 0,936 | 0,907 | 1,000 | 1,000 | 0,980 | 1,000 | 0,969 | 0,922 | 1,000 | 0,833 | 0,903 | 0,984 | 0,944 | 0,979 | 0,887 | 0,882 | 0,964 | 0,306 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A10** | 1,000 | 0,976 | 0,918 | 0,834 | 0,974 | 0,948 | 0,977 | 0,969 | 0,922 | 0,963 | 0,833 | 0,887 | 0,957 | 0,956 | 0,983 | 0,910 | 0,903 | 0,979 | 0,310 |
| **A11** | 0,944 | 0,976 | 0,943 | 0,777 | 1,000 | 0,948 | 0,977 | 0,987 | 0,922 | 0,963 | 0,833 | 0,924 | 0,984 | 0,945 | 0,986 | 0,963 | 0,961 | 1,000 | 0,357 |
| **A12** | 0,979 | 0,976 | 0,989 | 0,987 | 0,974 | 0,980 | 1,000 | 0,939 | 0,922 | 1,000 | 0,833 | 0,873 | 0,984 | 0,971 | 1,000 | 0,897 | 0,885 | 0,996 | 0,423 |