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Practical Overview of Triangular Bipolar Neutrosophic Numbers for Design Effect Evaluation of Ethnic Minority Clothing: Comprehensive Guide

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Abstract: This paper offers a novel multi-criteria decision-making (MCDM) paradigm to handle the problem of assessing and prioritizing design effect evaluation of ethnic minority clothing. The framework incorporates the ARTASI (Alternative Ranking Technique based on Adaptive Standardized Intervals) technique for objective alternative evaluation and CRITIC method for robust weight determination. This novel method, CRITIC-ARTASI, makes use of a unique algorithm for logical reasoning and makes it easier to make decisions while designing effect evaluation of ethnic minority clothing. 7 Criteria and 13 are used in this study. Sensitivity studies were used to thoroughly assess the correctness and stability of the suggested CRITIC-ARTASI framework. After fine-tuning the utility function's parameters to evaluate their impact, the model's rank is tested under different cases. The results show the ranks of the alternatives are stable under different cases.

Keywords: Triangular Bipolar Neutrosophic Numbers (TBNNs); Uncertainty; Decision Making; Ethnic Minority Clothing.

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1. Introduction and Literature Review

Zadeh introduced fuzzy set theory, which addresses the ideas of vagueness and uncertainty theory. To solve issues pertaining to statistical computation and engineering, vague theory is essential. It is frequently applied to social science, networking, decision-making, and other real-world issues. In 1986, Atanassov introduced the legerdemain concept of an intuitionistic fuzzy set in mathematics, based on Zadeh's paper[1], [2]. He took into consideration both the membership function and the non-membership function in the context of an intuitionistic fuzzy set. Later, in 2007, Liu and Yuan developed the idea of triangular intuitionistic fuzzy sets, which are a combination of intuitionistic fuzzy sets and triangle fuzzy sets.

Ye subsequently presented the basic concept of a trapezoidal intuitionistic fuzzy set, in which the truth function and falsity function are both trapezoidal numbers rather than triangular. The creation of intriguing models in a variety of domains with scientific and technical issues is influenced by uncertainty theory[3], [4]. But a simple question comes up: how can we apply or develop the concepts of uncertainty in our mathematical modeling in relation to everyday life? Scholars from all around the world have developed numerous strategies and techniques to define those ideas and have made various suggestions for applying uncertainty philosophy. Various suggestions for categorizing some of the fundamental confusing criteria are presented in the literature[5], [6]. It should be mentioned that the vague parameter does not have an exclusive representation.

The option made by the decision maker to solve an issue can be given in a variety of ways depending on the application. In 1995, Smarandache proposed the concept of a neutrosophic set consisting of three distinct elements: truthiness, indeterminacies, and falseness. Our real-world systems are highly applicable to every facet of the neutrosophic set[7], [8]. The neutrosophic concept is a fascinating and successful idea. The idea of a single typed neutrosophic set was further developed by Wang et al. and is highly helpful in resolving any complicated issue[9], [10]. Triangular neutrosophic was first conceptualized and classified by Chakraborty et al. Using the removal area method, Chakraborty et al. demonstrated the perception of defuzzification.

Multi-criteria decision-making problems are currently of great interest to researchers worldwide. A finite number of alternatives and a finite number of attributes with various weight function types for varying numbers of decision makers were taken into consideration for that kind of problem. This method's objective was to compare the alternatives and attributes while keeping the decision makers' weight in place so that we could quickly identify the best and worst options. Although multi-criteria decision-making (MCDM) difficulties have been the subject of numerous research proposals, we focused on and examined an MCDM problem in this novel triangular bipolar neutrosophic arena using our de-polarization technique.

1.1 Literature Review

Chakraborty et al. [11] contributed to the generalized neutrosophic number theory from a unique perspective. Positive, indeterminacy, and non-belongingness membership functions are widely recognized to be closely related to and commonly associated with the idea of a neutrosophic number. Now, every membership function falls between 0 and 1. Nonetheless, they have developed a bipolar idea in which the membership has both positive and negative components within the ranges of 0 to 1 and -1 to 0. Regarding the membership functions that contain dependency or independency with one another, they describe many structures of generalized TBNNs.

The interaction and dependency between fuzzy and crisp numbers are always of interest to researchers from various domains. To enable the seamless conversion of any bipolar neutrosophic fuzzy number of any kind into a real number instantaneously, they also developed the perception of de-bipolarization for TBNNs using well-known techniques. Compared to other methods, creating a problem utilizing bipolar neutrosophic perception is more accurate, dependable, and trustworthy.

Graph theory is an essential part of mathematics that is used to solve problems in a variety of fields. One of the new options that is appearing in a neutrosophic chromatic number environment is graph coloring. Sudha et al. [10] investigated and illustrated the algebraic assumption and presented the concept of BTN chromatic graphs.

Abdel-Basset et al. [12] offered a new hybrid neutrosophic MCDM framework that used TOPSIS under bipolar neutrosophic numbers and a collection of neutrosophic ANP. Elsewedy Electric Group in Egypt is the subject of a case study that applies the MCDM framework to the selection of CEOs. They can accurately pick personnel by using the suggested method to compile individual assessments of the decision makers.

To demonstrate and validate the results, the suggested method's output is contrasted with those of comparable works.

Deli et al. [13] presented the idea of a bipolar neutrosophic set and some of its operations in this work. To compare the bipolar neutrosophic sets, they also suggested score, certainty, and accuracy functions. Additionally, they developed a bipolar neutrosophic MCDM approach based on the score, certainty, and accuracy functions. In their approach, the evaluation values of alternatives attributes are expressed as bipolar neutrosophic numbers, which are then used to choose the most desirable option or options. Lastly, a numerical example was provided to show how the suggested method may be applied and how effective it is.

ELECTRE and TOPSIS techniques are popular approaches for resolving MCDM issues. To address such issues, Akram et al. [14] introduced the bipolar neutrosophic TOPSIS and ELECTRE-I methods. In our bipolar neutrosophic TOPSIS technique, they ranked alternatives using the updated closeness degree. Using flow charts, they explained the bipolar neutrosophic TOPSIS and ELECTRE-I methods. They used the suggested techniques to solve numerical examples. They compare these approaches as well.

2. Methodology

Triangular Bipolar Neutrosophic Numbers (TBNNs)

This section shows some definitions of TBNNs such as[11], [15]:

Definition 1.

We can define the single types neutrosophic number (STNN) such as:

$$z=\begin{pmatrix}[(p^1,q^1,r^1,s^1);a],\\ [(p^2,q^2,r^2,s^2);b],\\ [(p^3,q^3,r^3,s^3);c]\end{pmatrix} \tag{1}$$

$$T_z(x)=\begin{cases}T_{zl}(x) & p^1\le x\le q^1\\ a & q^1\le x\le r^1\\ T_{zu}(x) & r^1\le x\le s^1\\ 0 & otherwise\end{cases} \tag{2}$$

$$I_z(x)=\begin{cases}I_{zl}(x) & p^2\le x\le q^2\\ b & q^2\le x\le r^2\\ I_{zu}(x) & r^2\le x\le s^2\\ 1 & otherwise\end{cases} \tag{3}$$

$$F_z(x)=\begin{cases}F_{zl}(x) & p^3\le x\le q^3\\ c & q^3\le x\le r^3\\ F_{zu}(x) & r^3\le x\le s^3\\ 1 & otherwise\end{cases} \tag{4}$$

The triangular single typed bipolar neutrosophic number (TSBNN) such as:

$A=\{i_1,i_2,i_3;j_1,j_2,j_3,k_1,k_2,k_3\}$

$$T_A^+(x) = \begin{cases} \frac{x-i_1}{i_2-i_1} & i_1 \le x \le i_2 \\ 1 & x = i_2 \\ \frac{i_3-x}{i_3-i_2} & i_2 \le x \le i_3 \\ 0 & otherwise \end{cases} \quad (5)$$

$$T_A^-(x) = \begin{cases} \frac{i_1-x}{i_2-i_1} & i_1 \le x \le i_2 \\ -1 & x = i_2 \\ \frac{x-i_3}{i_3-i_2} & i_2 \le x \le i_3 \\ 0 & otherwise \end{cases} \quad (6)$$

$$I_A^+(x) = \begin{cases} \frac{j_2-x}{j_2-j_1} & j_1 \le x \le j_2 \\ 0 & x = j_2 \\ \frac{x-j_3}{j_3-j_2} & j_2 \le x \le j_3 \\ 0 & otherwise \end{cases} \quad (7)$$

$$I_A^-(x) = \begin{cases} \frac{x-j_2}{j_2-j_1} & j_1 \le x \le j_2 \\ 0 & x = j_2 \\ \frac{j_2-x}{j_3-j_2} & j_2 \le x \le j_3 \\ -1 & otherwise \end{cases} \quad (8)$$

$$F_A^+(x) = \begin{cases} \frac{k_2-x}{k_2-k_1} & k_1 \le x \le k_2 \\ 0 & x = k_2 \\ \frac{x-k_3}{k_3-k_2} & k_2 \le x \le k_3 \\ 1 & otherwise \end{cases} \quad (9)$$

$$F_A^-(x) = \begin{cases} \frac{x-k_2}{k_2-k_1} & k_1 \le x \le k_2 \\ 0 & x = k_2 \\ \frac{k_3-x}{k_3-k_2} & k_2 \le x \le k_3 \\ -1 & otherwise \end{cases} \quad (10)$$

$$-3 \le T_A(x) + I_A(x) + F_A(x) \le 2 \quad (11)$$

CRITIC Model

This methodology is used to compute the criteria weights. The steps of the CRITIC methodology are summarized as follows[16], [17]:

Step 1. Build the initial decision matrix

Step 2. Normalize the decision matrix for positive and negative criteria

$$x_{ij} = \frac{r_{ij}-r_i^-}{r_i^+-r_i^-} \quad (12)$$

$$x_{ij} = \frac{r_{ij}-r_i^+}{r_i^--r_i^+} \quad (13)$$

Step 3. Compute the correlation coefficient

Step 4. Compute the standard deviation

Step 5. Compute the index H

$$H_j = stand \sum_{k=1}^{n}(1 - \text{correlation coefficient}) \quad (14)$$

Step 6. Compute the criteria weights.

$$w_j = \frac{H_j}{\sum_{j=1}^{n} H_j} \quad (15)$$

Evaluation Model: ARTASI.

The ARTASI methodology is used to rank the alternatives. The steps of the ARTASI methodology are summarized as follows[18]:

Step 1. Build the initial decision matrix

$$f = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \quad (16)$$

Step 2. Compute the absolute max and min values.

$$p_j^{max} = \max_{1 \le i \le m}(r_{ij}) + \left\{\max_{1 \le i \le m}(r_{ij})\right\}^{\frac{1}{m}} \quad (17)$$

$$p_j^{min} = \min_{1 \le i \le m}(r_{ij}) + \left\{\min_{1 \le i \le m}(r_{ij})\right\}^{\frac{1}{m}} \quad (18)$$

Step 3. Normalize the initial decision matrix

The initial decision matrix is normalized such as:

$$n_{ij} = \frac{s^{(u)} - s^{(l)}}{p_j^{max} - p_j^{max}} r_{ij} + \frac{p_j^{max} s^{(u)} - p_j^{min} s^{(l)}}{p_j^{max} - p_j^{min}} \quad (19)$$

Where $s^{(u)}$ and $s^{(l)}$ refer to the upper and lower limits of normalized interval.

Change the values, if the criterion is of the min type

$$c_{ij} = -n_{ij} + \max_{1 \le i \le m}(n_{ij}) + \min_{1 \le i \le m}(n_{ij}) \quad (20)$$

Step 4. Compute the degree of usefulness of alternatives about optimal and suboptimal values.

$$y_{ij}^{+} = \frac{c_{ij}}{\max_{1 \le i \le m}(c_{ij})} w_j s^{(u)} \quad (21)$$

$$y_{ij} = \frac{\min_{1 \le i \le m}(c_{ij})}{c_{ij}} w_j s^{(u)} \quad (22)$$

$$y_{ij}^{-} = -y_{ij} + \max_{1 \le i \le m}(y_{ij}) + \min_{1 \le i \le m}(y_{ij}) \quad (23)$$

Step 5. Compute the combined level of usefulness of alternatives for ideal value and anti-ideal value

$$t_i^{+} = \sum_{j=1}^{n} y_{ij}^{+} \quad (24)$$

$$t_i^{-} = \sum_{j=1}^{n} y_{ij}^{-} \quad (25)$$

Step 6. Compute the ultimate utility functions and rank the alternatives

$$t_i = (t_i^+ + t_i^-)\{af(t_i^+) + (1-a)f(t_i^-)\} \quad (26)$$

$$f(t_i^+) = \frac{t_i^+}{t_i^+ + t_i^-} \quad (27)$$

$$f(t_i^-) = \frac{t_i^-}{t_i^+ + t_i^-} \quad (28)$$

Where a between 0 and 1.

3. Results and Discussion

This section shows the results of the proposed approach. Three experts have evaluated the criteria and alternatives. This study evaluated seven criteria and 13 alternatives. Then These experts have experience in the related filed of the decision-making problem. These criteria and alternatives are used to aid experts to compute the criteria weights and rank the alternatives based on set of steps. The criteria of this study as: Functionality, cost-effective, Marketability, Production Techniques, Cultural Authenticity, Design Quality, Material Selection. The alternatives of this study are: High-Fashion Ethnic Couture Daily Wear Adaptation of Ethnic Styles, Authentic Traditional Replication, Functional Ethnic Wear, Wearable Technology Integration, Digitally Enhanced Ethnic Patterns, Souvenir Clothing Collections, Modernized Ethnic Fashion Fusion, Avant-Garde Ethnic Designs, Sustainable Ethnic Clothing, Minimalist Ethnic Fashion Approach, Cultural Festival Costumes, Urban Ethnic Fashion.

Results of CRITIC Model

We used the CRITIC method to compute the criteria weights.

- Step 1. We built the decision matrix based on the neutrosophic numbers as shown in Tables 1-3.
- Step 2. Then we normalize the decision matrix using Eq. (12) as shown in Table 4.
- Step 3. Then we compute the correlation coefficient as shown in Fig 1.
- Step 4. Then we compute the standard deviation for the criteria.
- Step 5. Eq. (14) is used to compute the H_j values as shown in fig 2.
- Step 6. Eq. (15) is used to compute the criteria weights as shown in fig 3.

Table 1. The first TBNNs.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)
A_2	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)
A_3	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)
A_4	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)
A_5	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,3,5;0.5,2.5,4.5;2,4,6)
A_6	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)
A_7	(1,5,8;0.5,3,6;3.5,7,.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(2,4,6;1.5,2.5,3.5;3,5,7)
A_8	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,5,8;0.5,3,6;3.5,7,.5)
A_9	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)
A_{10}	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,5,8;0.5,3,6;3.5,7,.5)

A_{11}	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)
A_{12}	(1,5,8;0.5,3,6;3.5,7,.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)
A_{13}	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)

Table 2. The second TBNNs.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)
A_2	(2,4,6;1.5,2.5,3.5;3,5,7)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)
A_3	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)
A_4	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)
A_5	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)
A_6	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)
A_7	(2,4,6;1.5,2.5,3.5;3,5,7)	(2,4,6;1.5,2.5,3.5;3,5,7)	(2,4,6;1.5,2.5,3.5;3,5,7)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)
A_8	(1,5,8;0.5,3,6;3.5,7,.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,3,5;0.5,2.5,4.5;2,4,6)
A_9	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)
A_{10}	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)
A_{11}	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)
A_{12}	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)
A_{13}	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)

Table 3. The third TBNNs.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)
A_2	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)
A_3	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,5,8;0.5,3,6;3.5,7,.5)
A_4	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(2,4,6;1.5,2.5,3.5;3,5,7)
A_5	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)
A_6	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)
A_7	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)
A_8	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)
A_9	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)
A_{10}	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,5,8;0.5,3,6;3.5,7,.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,5,8;0.5,3,6;3.5,7,.5)
A_{11}	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,5,8;0.5,3,6;3.5,7,.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(2,4,6;1.5,2.5,3.5;3,5,7)
A_{12}	(1,5,8;0.5,3,6;3.5,7,.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,2,3;0.5,1.5,2.5;1.3,2.5,3.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(1,4,7;0.5,2,3;3.5,5.5,7.5)
A_{13}	(2,4,6;1.5,2.5,3.5;3,5,7)	(1,4,7;0.5,2,3;3.5,5.5,7.5)	(1,3,5;0.5,2.5,4.5;2,4,6)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(0.5,2.5,4.5;1,2,3;1.5,3.5,5.5)	(0.6,2,4;0.3,1,1.25;1.5,3,4.5)	(1,3,5;0.5,2.5,4.5;2,4,6)

Table 4. The normalization of TBNNs by the CRITIC method.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.322264	1	0.910221	0.882839	0.610108	0.013619	0.084302
A_2	0.453585	0	0.004834	0.676085	0.935018	0.863813	0
A_3	0.775849	0.377143	0.889503	0.682977	0.318412	1	1
A_4	0.536604	0.533333	0.700276	0.339766	0.433935	0	0.771802

A_5	0.660377	0.364762	0.716851	0.339766	0.484477	0.212711	0.412791
A_6	0.871698	0.485714	0.594613	0.407305	0.118412	0.392348	0.651163
A_7	0.723019	0.374286	0.799724	0	0.518412	0.476654	0.034884
A_8	0.387925	0.6	1	0.490007	0.833935	0.798962	0.767442
A_9	0.242264	0.020952	0.296961	0.284631	1	0.56939	0.116279
A_{10}	0.366038	0.177143	0.571823	1	0.686643	0.727626	0.863372
A_{11}	0	0.38381	0	0.951757	0.484477	0.337873	0.898256
A_{12}	0.984906	0.628571	0.578729	0.583735	0	0.290532	0.640988
A_{13}	1	0.771429	0.578729	0	0.436823	0.013619	0.607558

Fig 1. The correlation between criteria.

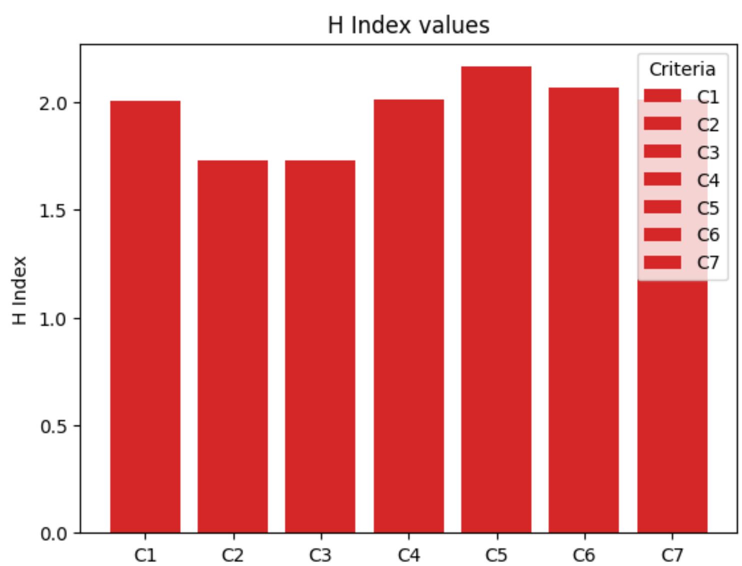

Fig 2. The H_j values.

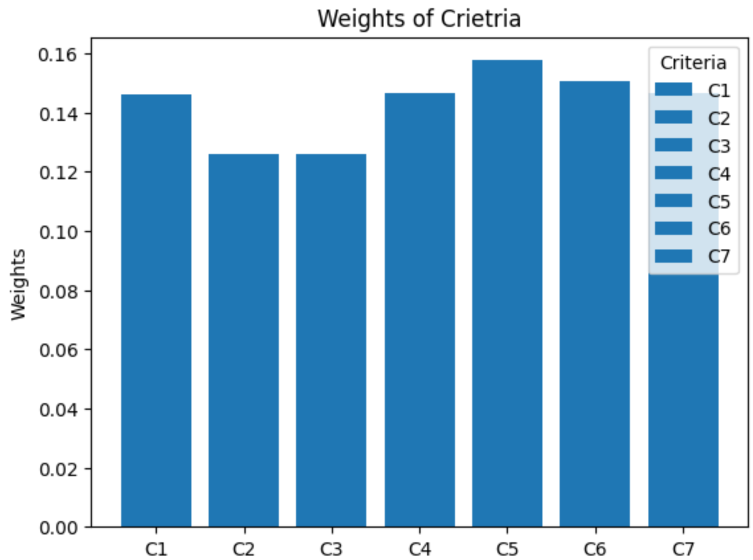

Fig 3. The criteria weights.

Evaluation Model: ARTASI.

We used the ARTASI to rank the alternatives.

- Step 1. Eq. (16) is used to build the initial decision matrix
- Step 2. Eq. (17) and (18) are used to compute the absolute max and min values.
- Step 3. Eq. (19) is used to normalize the initial decision matrix as shown in Table 5.
- Eq. (20) is used to change the values, if the criterion is of the min type as shown in Table 6.
- Step 4. Eqs. (21,22,23) are used to Compute the degree of usefulness of alternatives about optimal and suboptimal values.
- Step 5. Eqs. (24 and 15) are used to compute the combined level of usefulness of alternatives for ideal value and anti-ideal value as shown in Tables 7 and 8.
- Step 6. Eqs. (27,28,29) are used to compute the ultimate utility functions and rank the alternatives as shown in fig 4. we put the a with 0.5 as shown in Table 9.

Table 5. The normalization of TBNNs.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	3.472884	5.482748	3.817882	3.798251	3.633656	2.88445	6.403223
A_2	3.589259	4.594568	3.015231	3.614948	3.921634	3.638286	6.328438
A_3	3.874843	4.929539	3.799515	3.621058	3.375116	3.759038	7.215542
A_4	3.662828	5.068264	3.63176	3.316774	3.477508	2.872375	7.013107
A_5	3.772514	4.918542	3.646454	3.316774	3.522305	3.060978	6.694627
A_6	3.959783	5.02597	3.538087	3.376653	3.19785	3.220255	6.906087
A_7	3.828026	4.927001	3.719923	3.015546	3.552383	3.295006	6.359384
A_8	3.531071	5.127476	3.897474	3.449975	3.832041	3.580786	7.009239
A_9	3.40199	4.613178	3.27421	3.267893	3.97923	3.377232	6.43159
A_{10}	3.511676	4.751903	3.517883	3.902123	3.701491	3.517535	7.094339
A_{11}	3.1873	4.93546	3.010946	3.859353	3.522305	3.171954	7.125285
A_{12}	4.060105	5.152853	3.524005	3.533072	3.092898	3.129979	6.897062

A_{13}	4.073482	5.279735	3.524005	3.015546	3.480068	2.88445	6.867406

Table 6. The change values.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	10.73367	15.56006	10.7263	10.71592	10.70578	9.515863	19.9472
A_2	10.85004	14.67188	9.92365	10.53262	10.99376	10.2697	19.87242
A_3	11.13562	15.00685	10.70793	10.53873	10.44724	10.39045	20.75952
A_4	10.92361	15.14558	10.54018	10.23444	10.54964	9.503788	20.55709
A_5	11.0333	14.99586	10.55487	10.23444	10.59443	9.69239	20.23861
A_6	11.22056	15.10329	10.44651	10.29432	10.26998	9.851668	20.45007
A_7	11.08881	15.00432	10.62834	9.933215	10.62451	9.926419	19.90336
A_8	10.79185	15.20479	10.80589	10.36764	10.90417	10.2122	20.55322
A_9	10.66277	14.69049	10.18263	10.18556	11.05136	10.00865	19.97557
A_{10}	10.77246	14.82922	10.4263	10.81979	10.77362	10.14895	20.63832
A_{11}	10.44808	15.01278	9.919365	10.77702	10.59443	9.803367	20.66927
A_{12}	11.32089	15.23017	10.43242	10.45074	10.16503	9.761392	20.44104
A_{13}	11.33426	15.35705	10.43242	9.933215	10.5522	9.515863	20.41139

Table 7. The ideal values.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.138579	0.125865	0.125009	0.14537	0.152708	0.137977	0.141046
A_2	0.140082	0.118681	0.115654	0.142883	0.156816	0.148907	0.140517
A_3	0.143769	0.121391	0.124795	0.142966	0.149021	0.150658	0.14679
A_4	0.141032	0.122513	0.122839	0.138839	0.150481	0.137802	0.145358
A_5	0.142448	0.121302	0.123011	0.138839	0.15112	0.140537	0.143106
A_6	0.144866	0.122171	0.121748	0.139651	0.146492	0.142846	0.144601
A_7	0.143164	0.12137	0.123867	0.134752	0.151549	0.14393	0.140736
A_8	0.139331	0.122992	0.125936	0.140645	0.155538	0.148074	0.145331
A_9	0.137664	0.118832	0.118672	0.138175	0.157638	0.145122	0.141246
A_{10}	0.13908	0.119954	0.121512	0.146779	0.153676	0.147157	0.145933
A_{11}	0.134892	0.121438	0.115604	0.146199	0.15112	0.142146	0.146151
A_{12}	0.146161	0.123197	0.121584	0.141773	0.144995	0.141537	0.144538
A_{13}	0.146333	0.124223	0.121584	0.134752	0.150518	0.137977	0.144328

Table 8. The anti-ideal values.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.138945	0.125865	0.125078	0.145473	0.152957	0.137993	0.141067
A_2	0.140473	0.118681	0.115659	0.143105	0.156878	0.149038	0.140517
A_3	0.144087	0.12149	0.124879	0.143185	0.149253	0.150658	0.14679
A_4	0.141422	0.122618	0.123022	0.139072	0.150742	0.137802	0.145406
A_5	0.142813	0.1214	0.123187	0.139072	0.151384	0.140734	0.143173
A_6	0.145126	0.122276	0.121959	0.139901	0.146606	0.143122	0.144663
A_7	0.143507	0.12147	0.124005	0.134752	0.151813	0.144216	0.140745
A_8	0.139713	0.123092	0.125936	0.140903	0.155681	0.148253	0.145379
A_9	0.137998	0.11884	0.11886	0.138389	0.157638	0.145402	0.141275
A_{10}	0.139458	0.120016	0.121727	0.146779	0.1539	0.147379	0.145964
A_{11}	0.135052	0.121539	0.115604	0.146244	0.151384	0.142406	0.146176
A_{12}	0.146333	0.123295	0.121798	0.142021	0.144995	0.141778	0.1446
A_{13}	0.146493	0.124297	0.121798	0.134752	0.150779	0.137993	0.144393

Table 9. The alternative method results.

	t_i^+	t_i^-	$f(t_i^+)$	$f(t_i^-)$	t_i
A_1	0.966555	0.96738	0.499787	0.500213	1.450245
A_2	0.963541	0.964351	0.49979	0.50021	1.445716
A_3	0.979389	0.980342	0.499757	0.500243	1.46956
A_4	0.958864	0.960083	0.499682	0.500318	1.438905
A_5	0.960362	0.961763	0.499635	0.500365	1.441243
A_6	0.962374	0.963653	0.499668	0.500332	1.444201
A_7	0.959368	0.960508	0.499703	0.500297	1.439622
A_8	0.977847	0.978957	0.499716	0.500284	1.467325
A_9	0.95735	0.958401	0.499726	0.500274	1.43655
A_{10}	0.974091	0.975224	0.499709	0.500291	1.461703
A_{11}	0.957551	0.958405	0.499777	0.500223	1.436754
A_{12}	0.963784	0.96482	0.499731	0.500269	1.446194
A_{13}	0.959715	0.960504	0.499795	0.500205	1.439967

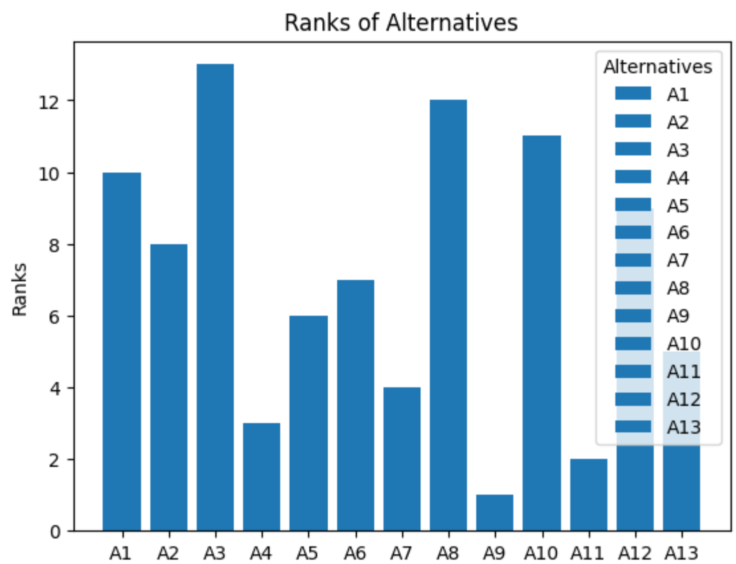

Fig 4. The rank of alternatives.

4. Analysis

The sensitivity analysis and validation methods used for the results obtained using the ARTASI model are described in this section. There are two successive stages to the sensitivity analysis. First, attention is focused on how the utility function's parameters (α) change. The discussion then moves on to changing threshold values within the criterion period. Additionally, the results generated by the MCDM models are under consideration compared with a statistical correlation to the preliminary results.

In the following part, the sensitivity of the model was analyzed in 11 scenarios in which the utility function's parameter varied systematically. In the first scenario, a = 0 was adopted, and for each following scenario, parameter a was successively increased by 0.1. These modifications affected the utility function's transformation and, as a result, changed the alternatives' final values. Fig 5 shows the utility function values. Fig 6 shows the ranks of the alternatives.

Alternative 3 is the best and alternative 9 is the worst. We show the ranks of the alternatives under different cases are stable.

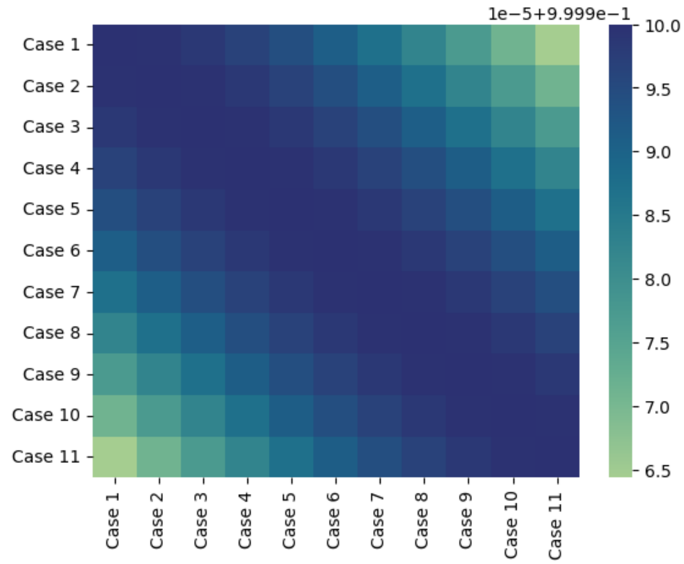

Fig 5. The utility functions values.

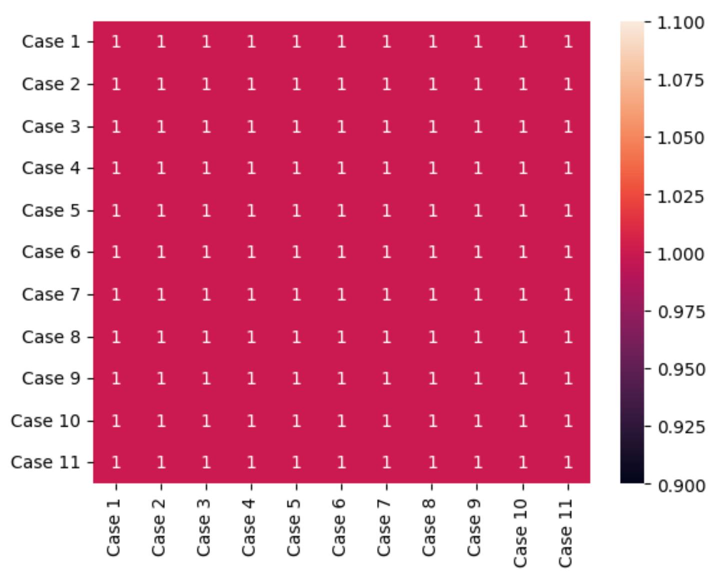

Fig 6. The rank of the alternatives under different cases.

Advantages of Proposed Method

The CRITIC method is a powerful objective weight determination technique used in MCDM. It assigns weights to criteria based on the contrast intensity (variance) and the degree of conflict (correlation) between criteria. Here are its key advantages:

1. Objective Weight Calculation

Unlike subjective weighting methods (e.g., AHP, SWARA), CRITIC assigns weights based on mathematical calculations rather than expert judgment. This eliminates human bias and makes the process more data-driven and reliable.

2. Considers Both Variability and Interdependencies

CRITIC evaluates two essential factors:

- Contrast intensity (higher variance means a criterion is more important).
- Correlation between criteria
- This ensures that less redundant and more informative criteria receive higher weights.

3. Effective Large-Scale Decision Problems

Since it is purely statistical, CRITIC works well in large and complex decision-making problems, where many criteria must be evaluated simultaneously.

4. Eliminates Subjectivity and Bias

Because the weights are computed using standard deviation and correlation coefficients, the method does not require human input, reducing subjective inconsistencies.

5. Compatible with Other MCDM Methods

CRITIC is frequently combined with methods like TOPSIS, ARAS, COPRAS, and MABAC to enhance decision-making accuracy by providing more reliable weight values.

6. Ensures Data-Driven Decision Making

By relying on statistical measures rather than personal judgment, CRITIC enhances the credibility and transparency of the decision-making process.

7. Suitable for Various Fields

5. Conclusions

This study used the new CRITIC-ARTASI multi-criteria decision-making model to evaluate the effectiveness of 13 alternatives. We have identified 7 criteria in this study. A unique CRITIC approach is used to compute the criteria weights for the seven criteria. According to the findings, the CRITIC-ARTASI multi-criteria decision-making model, when combined with rankings, offers a solid and reliable framework for assessing design effect evaluation of ethnic minority clothing. The results show alternative 3 is the best and alternative 9 is the worst. The sensitivity analysis is conducted to show the stability of the ranks.

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