Neutrosophic Multi-Criteria Decision-Making Methodology to Identify Key Barriers in Education

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Abstract

Various educational barriers have negative impacts on teachers, organizations, and students. Identify these barriers and introduce some strategies that give benefits to organizations. There are different conflicting barriers, so the concept of multi-criteria decision-making (MCDM) is used to deal with these barriers. We proposed an MCDM Framework to evaluate the education barriers and rank strategies to select the best one. We suggest a TOPSIS method to rank the alternatives. The TOPSIS method is integrated with the neutrosophic set to deal with uncertain information. The weights of the criteria are computed with the mean method. We collected ten barriers and nine strategies in this study. The results show that Promoting teacher motivation is the best of the nine strategies. We created a sensitivity analysis to show the model's effectiveness and the results' stability. The sensitivity analysis is made by changing the criteria weights and ranking the strategies. The results show that promoting teacher motivation is the best in all cases in sensitivity analysis.

Keywords: Neutrosophic Sets; MCDM; Uncertainty; Education; Decision Making; Decision Tools

1. Introduction

There has been a lot of study on the role that perceptions of difficulty have in people's judgments and preferences about involvement. The obstacles to learning may be broken down into three broad categories: institutional, contextual, and personal.

Some populations are persistently disadvantaged by institutional impediments such as rules, processes, or exclusion criteria. These include insufficient access to qualified instructors or bad relevant course offerings. Problems with scheduling, getting to and from school, finding appropriate classes, completing necessary paperwork promptly, and not knowing what to do are all examples of institutional hurdles[1], [2].

Situational obstacles are inherent to a person's current circumstances, such as family and living situations. Worrying about bills, getting to work, or caring for kids are all examples.

Attitudes and beliefs about one's abilities as a student are at the heart of dispositional hurdles. The belief that one is too old to learn, a lack of motivation to study, or a lack of self-assurance. Adults from disadvantaged socioeconomic backgrounds tend to have low reading levels, which may further affect their confidence in their abilities to finish a formal schooling program[3], [4].

Cross has admitted that classifying certain things may be a matter of personal preference but strives to fit them into the category that appears "most direct and straightforward" in her work. She uses a lack of knowledge as an example, noting that this can be a situational barrier if, for instance, poor people rarely receive details on adult learning courses

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or a behavioral barrier if, for instance, some adults will put forth little effort to inform themselves about possibilities for learning[5], [6].

Similar categories to Cross have been used. Some scholars classify difficulties in accessing and processing information as a separate category, attributing it to institutional inefficiency and human laziness. Dispositional obstacles are also frequently referred to as attitudinal, motivational, and psychological hurdles. They are connected to bad attitudes toward education, learning challenges, values, or the subjective perception of abilities to attain desired objectives[7]–[9].

The multi-criteria decision-making method (MCDM) can identify and evaluate these barriers due to education having various criteria[10], [11]. The concept of MCDM deals with multiple criteria and can be ranked[12], [13]. The TOPSIS method is an MCDM method used to rank alternatives. All of the methods are only guaranteed to provide the best results. The TOPSIS approach is an excellent example of a solution-providing strategy[14]–[16]. The primary principle of TOPSIS is to find the answer closest to the positive ideal solution (PIS) and the furthest from the negative perfect solution (NIS)[17]–[19].

Decisions about the MCDM's assessment are made by eliminating possible ratings from consideration when the criteria's weights are adjusted[20], [21]. As a result, the overall assessment is impossible due to a lack of information about them and the fact that time constraints, partial knowledge, inadequate attribute information, and a lack of information about the decision-makers all play a role. When making choices in a group, it's crucial to have a precise understanding of weights to manage MCDM challenges effectively[22]–[24]. This study integrates a neutrosophic set (NS) with the TOPSIS method to overcome uncertain information. The NS has three values: truth, indeterminacy, and falsity memberships degrees.

The main contributions of this study are organized as follows: - It is the first study to identify the key barriers to education and rank the set strategies to overcome these barriers. - The concept of MCDM is used to deal with various criteria and rank the strategies. - The neutrosophic framework deals with uncertain information in the evaluation process. - The neutrosophic set is integrated with the TOPSIS method to show the rank of strategies. - The sensitivity analysis is created to show the model's effectiveness and the results' stability.

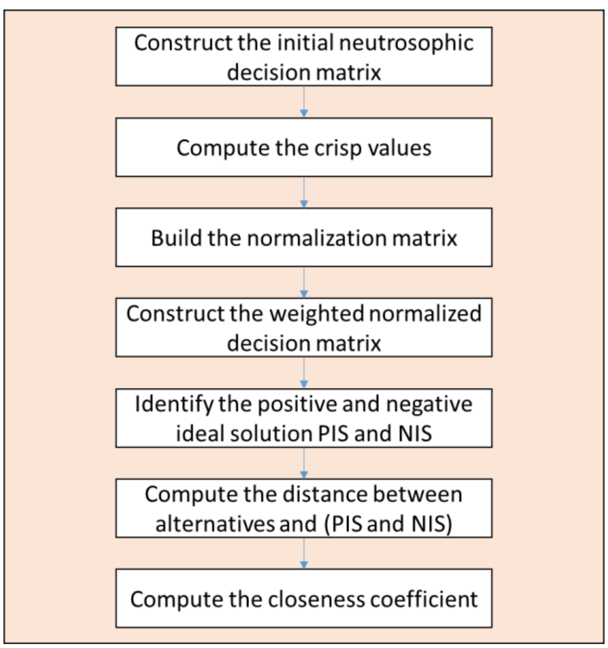

Figure 1: The framework of this study.

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2. Methodology

To properly account for the ambiguity in the specialist's judgment, neutrosophic logic employs the three components of truth (A_π), falsehood (B_π), and indeterminacy (C_π). Information inconsistency may be represented using generic triangular fuzzy numbers, which may or may not be adequate for a full representation[25].

$$\mu_\pi(y) = \begin{cases} \frac{(y-\pi_1)A_\pi}{(\pi_2-\pi_1)} & \pi_1 \leq y \leq \pi_2 \\ A_\pi & \pi_2 \leq y \leq \pi_3 \\ \frac{(\pi_4-y)A_\pi}{(\pi_4-\pi_3)} & \pi_3 \leq y \leq \pi_4 \\ 0 & otherwise \end{cases} \quad (1)$$

$$\lambda_\pi(y) = \begin{cases} \frac{(\pi_2-y+B_\pi(y-\pi_1))}{(\pi_2-\pi_1)} & \pi_1 \leq y \leq \pi_2 \\ B_\pi & \pi_2 \leq y \leq \pi_3 \\ \frac{(y-\pi_3+B_\pi(\pi_4-y))}{(\pi_4-\pi_3)} & \pi_3 \leq y \leq \pi_4 \\ 0 & otherwise \end{cases} \quad (2)$$

$$\upsilon_\pi(y) = \begin{cases} \frac{(\pi_2-y+C_\pi(y-\pi_1))}{(\pi_2-\pi_1)} & \pi_1 \leq y \leq \pi_2 \\ C_\pi & \pi_2 \leq y \leq \pi_3 \\ \frac{(y-\pi_3+C_\pi(\pi_4-y))}{(\pi_4-\pi_3)} & \pi_3 \leq y \leq \pi_4 \\ 0 & otherwise \end{cases} \quad (3)$$

The score function, accuracy, and certainty can be computed for Single Valued Trapezoidal Neutrosophic Numbers (SVTNSs) as:

$$S(\pi) = \frac{(\pi_1+2\pi_2+2\pi_3+\pi_4)(2+A_\pi+B_\pi+C_\pi)}{18} \quad (4)$$

$$Acc(\pi) = \frac{(\pi_1+2\pi_2+2\pi_3+\pi_4)(A_\pi-C_\pi)}{6} \quad (5)$$

$$Cer(\pi) = \frac{(\pi_1+2\pi_2+2\pi_2+\pi_4)A_\pi}{6} \quad (6)$$

The steps of the neutrosophic TOPSIS are organized as:

Step 1: Construct the initial neutrosophic decision matrix

We construct the neutrosophic decision matrix between criteria and alternatives. The set of criteria can be represented as $BEC_1, BEC_2 \dots \dots BEC_j; j = 1,2,3, \dots n$ and the set of alternatives can be represented as $BEA_1, BEA_2, \dots \dots . BEA_i; i = 1,2,3, \dots . m$. The initial decision matrix can be defined as:

$$X = [x_{ij}]_{(m+1)\times n} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (7)$$

Step 2. Compute the crisp values

Apply the score function as in Eq. (4) to compute the crisp values instead of neutrosophic numbers.

Step 3. Build the normalization matrix

We build the normalization after computing the crisp values by the score function as:

$$L_{ij} = \frac{x_{ij}}{\sqrt{x_{ij}^2}} \quad (8)$$

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Step 4. Construct the weighted normalized decision matrix

First, we compute the weights of the criteria by letting the experts and decision-makers evaluate the criteria by using linguistic variables of the neutrosophic set. Then we apply the mean method to compute the weights of the criteria. Then we multiply the criteria weights by the normalization values to construct the weighted normalization matrix as:

$$WL_{ij} = w_j * L_{ij} \quad (9)$$

Step 5. Identify the positive and negative ideal solutions of PIS and NIS

The positive ideal solution and negative ideal solution can be defined as:

$$PIS_j^+ = \max WL_j \quad (10)$$

$$NIS_j^- = \min WL_j \quad (11)$$

Step 6. Compute the distance between alternatives and (PIS and NIS)

$$t_i^+ = \sum_{j=1}^{n} \sqrt{\left(PIS_j^+ - WL_{ij}\right)^2} \quad (12)$$

$$t_i^- = \sum_{j=1}^{n} \sqrt{\left(NIS_j^- - WL_{ij}\right)^2} \quad (13)$$

Step 7. Compute the closeness coefficient

The closeness coefficient is used to rank the alternatives by using the distance of all alternatives from PIS and NIS.

$$CC_i = \frac{t_i^-}{t_i^- + t_i^+} \quad (14)$$

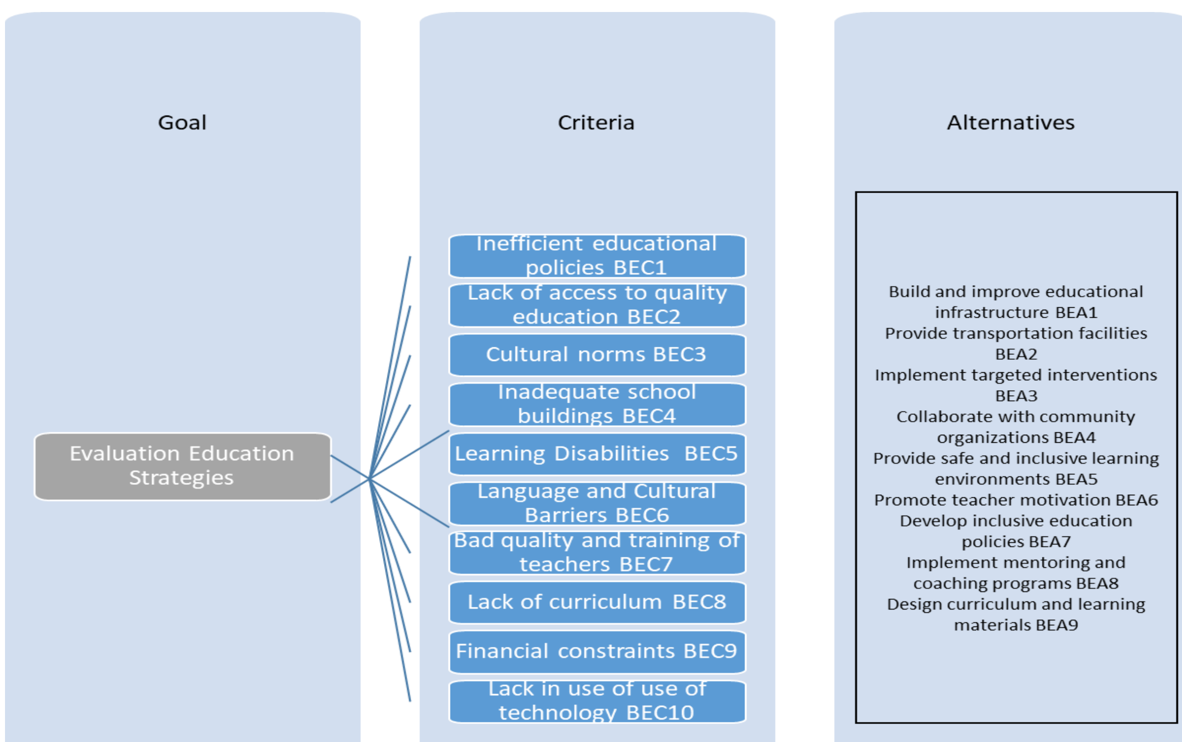

Figure 2: The barriers and key strategies of Education.

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3. Results and Discussion

In this section, we analyze the results of the key barriers in education and key strategies to overcome these barriers. The criteria and alternatives are shown in Figure 2.

Step 1. We used the linguistic variables[25] of neutrosophic numbers to evaluate the criteria and alternatives by the experts and decision-makers by building the decision matrix. The decision matrix is built by using Eq. (1).

Step 2. Eq. (4) is used to convert the neutrosophic numbers to the crisp values.

Step 3. Eq. (8) is used to normalize the decision matrix between criteria and alternatives as shown in Table 1.

Table 1: The normalization decision matrix between criteria and alternatives.

	BEC_1	BEC_2	BEC_3	BEC_4	BEC_5	BEC_6	BEC_7	BEC_8	BEC_9	BEC_{10}
BEA_1	0.24479	0.265555	0.095365	0.388942	0.162991	0.268866	0.274349	0.102101	0.336122	0.134058
BEA_2	0.367186	0.377679	0.333779	0.164085	0.162991	0.268866	0.390186	0.340336	0.210077	0.201088
BEA_3	0.24479	0.265555	0.211923	0.364633	0.407478	0.168041	0.390186	0.255252	0.336122	0.297908
BEA_4	0.367186	0.377679	0.333779	0.164085	0.579524	0.268866	0.365799	0.102101	0.210077	0.134058
BEA_5	0.24479	0.265555	0.339077	0.364633	0.162991	0.268866	0.390186	0.340336	0.210077	0.201088
BEA_6	0.367186	0.580286	0.143048	0.597591	0.244487	0.4131	0.384089	0.357353	0.516436	0.446861
BEA_7	0.24479	0.265555	0.520975	0.364633	0.407478	0.4131	0.16461	0.557771	0.094534	0.732354
BEA_8	0.543979	0.159333	0.520975	0.164085	0.162991	0.4131	0.384089	0.357353	0.315115	0.201088
BEA_9	0.24479	0.265555	0.211923	0.10939	0.407478	0.4131	0.10974	0.340336	0.516436	0.134058

Step 4. Eq. (9) is used to compute the weighted normalized decision matrix as shown in Table 2. Figure 3 shows the criteria weights.

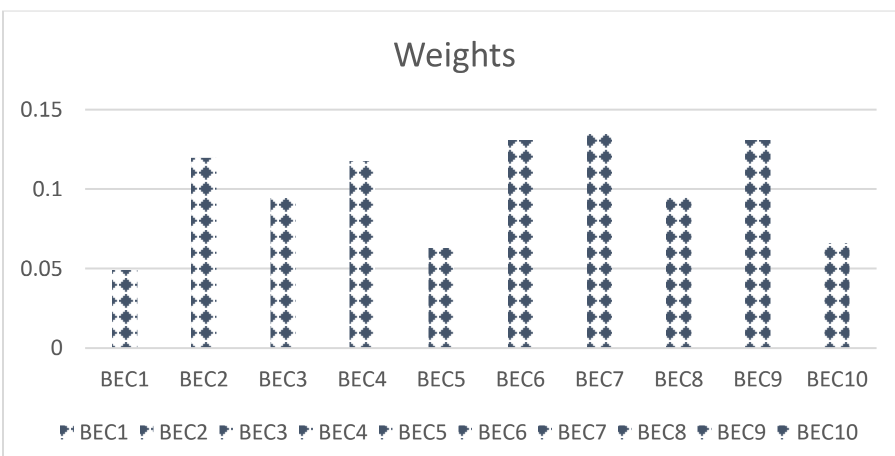

Figure 3: The weights of barriers in education.

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Table 2: The weighted normalized decision matrix.

	BEC_1	BEC_2	BEC_3	BEC_4	BEC_5	BEC_6	BEC_7	BEC_8	BEC_9	BEC_{10}
BEA_1	0.011983	0.031776	0.008966	0.045633	0.010258	0.035097	0.036878	0.009758	0.043876	0.008854
BEA_2	0.017974	0.045192	0.031381	0.019252	0.010258	0.035097	0.052449	0.032526	0.027423	0.013281
BEA_3	0.011983	0.031776	0.019924	0.042781	0.025645	0.021935	0.052449	0.024395	0.043876	0.019675
BEA_4	0.017974	0.045192	0.031381	0.019252	0.036474	0.035097	0.049171	0.009758	0.027423	0.008854
BEA_5	0.011983	0.031776	0.031879	0.042781	0.010258	0.035097	0.052449	0.032526	0.027423	0.013281
BEA_6	0.017974	0.069436	0.013449	0.070114	0.015387	0.053924	0.05163	0.034153	0.067414	0.029513
BEA_7	0.011983	0.031776	0.048981	0.042781	0.025645	0.053924	0.022127	0.053307	0.01234	0.048368
BEA_8	0.026628	0.019066	0.048981	0.019252	0.010258	0.053924	0.05163	0.034153	0.041134	0.013281
BEA_9	0.011983	0.031776	0.008966	0.045633	0.010258	0.035097	0.036878	0.009758	0.043876	0.008854

Step 5. Eqs. (10 and 11) are used to obtain the positive and negative ideal solution.

Step 6. Eqs. (12 and 13) are used to compute the distance from all alternatives and PIS and NIS.

Step 7. Eq. (14) is used to compute the closeness values to rank the alternatives as shown in Figure 4.

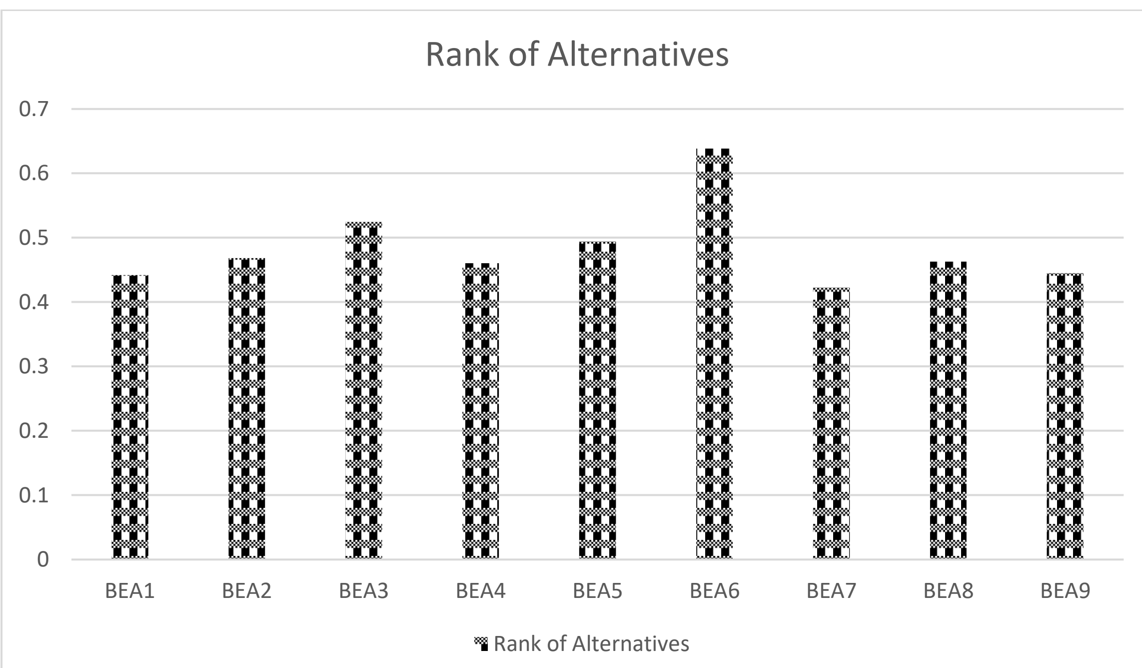

Figure 4: The rank of strategies in education barriers.

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3.1 Discussion of Results

In this part, we discuss the results obtained from the proposed methodology (N-TOPSIS). First, we collect the criteria and alternatives from previous studies. We manage ten criteria and nine alternatives related to barriers to education and a set of strategies to overcome the barriers in education, as shown in Figure 2. We let the experts and decision-makers evaluate the criteria to compute the criteria weights. The experts used the linguistics variables of single-valued trapezoidal neutrosophic numbers (SVTNNs). Then, we replaced these linguistic variables of SVTNNs[25] with crisp values using Eq. (4). Then, we used the mean method to compute the criteria weights, as shown in Figure 3. The weights of criteria show Bad quality and training of teachers as the highest criteria followed by the Language and Cultural Barriers, and the most minor barrier is the Inefficient educational policies.

In the next step, we apply the N-TOPSIS method to show the best strategy in education. We let the experts and decision-makers evaluate the criteria and alternatives to build the decision matrix. Then, normalize the decision matrix as shown in Table 1. Then, we multiply the criteria weights by the normalization matrix to obtain the weighted normalized decision matrix, as shown in Table 2. Then, get the positive and negative ideal solutions. Then, compute the distance from each alternative and the positive and negative perfect solution. Then, calculate the closeness coefficient to rank the alternatives. The results show that Promoting teacher motivation is the best strategy, followed by Implementing targeted interventions, and the least strategy is Developing inclusive education policies.

4. Analysis

In this section, we introduce the sensitivity analysis to show the stability of the results. We change the weights of criteria and rank the alternatives to show the best strategy under different weights of criteria. We propose eleven cases of change in the weights of criteria as shown in Figure 5. In case one, we put the weights of the criteria equal. Then in the other case, we put one criterion with 0.13 weight, and the other weights are equal.

Figure 6 shows the rank of alternatives under eleven cases in changing the weights of criteria. We show the BEA6 is the best alternative in all cases. This indicates our proposed model is efficient and the results are stable according to the sensitivity analysis results.

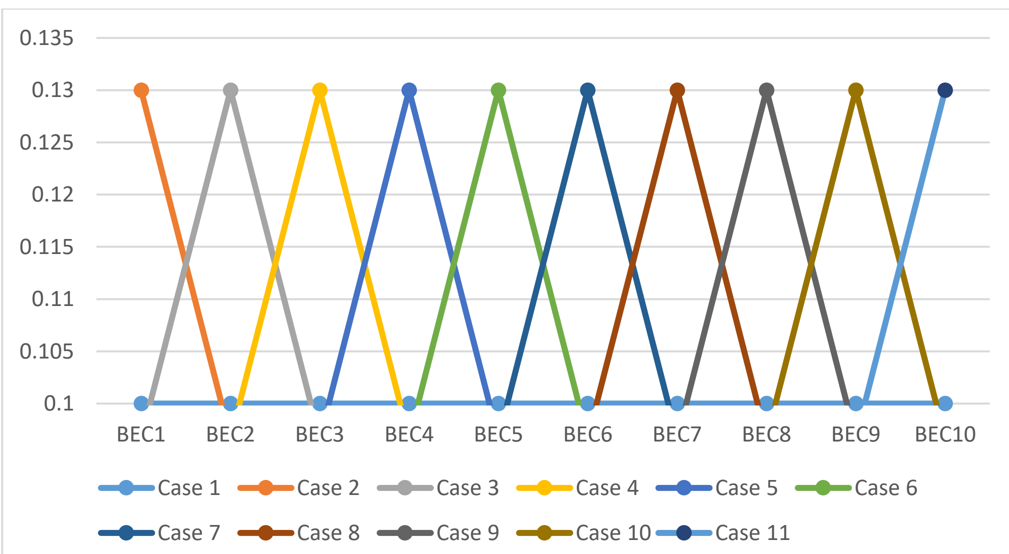

Figure 5: The eleven cases in changing the weights of criteria.

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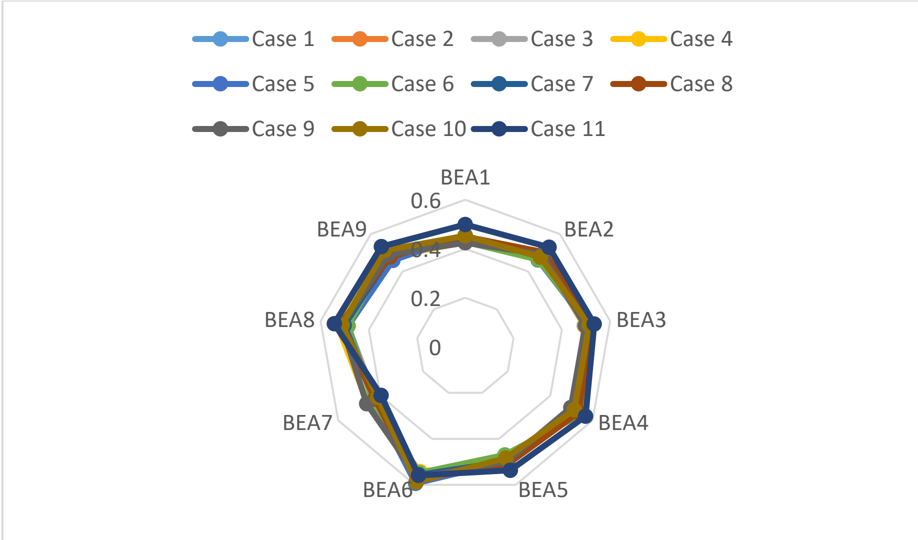

Figure 6: The rank of alternatives under different weights of criteria.

5. Implications

Evaluating critical barriers and selecting the best strategy has various implications for organizations, policymakers, and stakeholders. The managerial implications of this study are organized as follows:

Collecting the data from parts of education like students, teachers, and parents can provide a more suitable understanding of the barriers and give feedback to overcome these barriers.

Identify the barriers to education and evaluate the key strategies to overcome these barriers, such as financial, human, and technological.

Identifying the barriers can address the partnership to collect the resources and expertise.

6. Conclusions

Several significant obstacles in the field of education might impede one's ability to study and restrict their access to educational opportunities. Governments, schools, neighborhoods, and all interested parties must work together to remove these roadblocks. Solutions to these problems include addressing the digital divide, enhancing infrastructure, increasing access to excellent education, fostering gender equality, bolstering the professional development of educators, creating a curriculum that is both diverse and sensitive to cultural norms, and promoting gender equality. Education systems may get closer to their goal of making education accessible to all people if they consider these obstacles. In this study, we collect the ten criteria and nine alternatives to evaluate the barriers to education and select the best strategy to overcome these barriers. We let the experts assess the criteria and alternatives by using linguistic terms. The single-valued trapezoidal neutrosophic numbers replace the linguistic terms. The mean method is used to compute the weights of the criteria. The BEC7 is the highest barrier, and BEC1 is the lowest barrier. The TOPSIS method is used to rank the set of strategies. The decision matrix is built based on the criteria and alternatives. The TOPSIS method shows that BEA6 is the best and BEA7 is the worst. We change the criteria weights by the eleven cases to demonstrate the effectiveness of the proposed model. Then, we used the eleven cases of changing the criteria weights and ranking the strategies. We offer that the BEA6 is the best when changing the criteria weights in all cases.

In future studies, the proposed model can be applied in various decision-making models such as wind turbines, energy, personnel selection, and disease evaluation. This problem can be solved with uncertainty frameworks such as fuzzy sets and spherical fuzzy sets.

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