Multicriteria Algorithms with Applications

Journal Homepage: sciencesforce.com/mawa

Multicriteria. Algo. Appl. Vol. 2 (2024) 43–52.

Paper Type: Original Article

A Deeper Monitoring and Evaluation of the Nature of Barriers to Climate Change Adaptation Planning under Fuzzy Multi-Criteria Decision Making Methodology

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Received: 04 Sep 2023 **Revised:** 30 Dec 2023 **Accepted:** 14 Jan 2024 **Published:** 17 Jan 2024

Abstract

This study developed a decision-making model to evaluate the barriers to climate change. The climate change barriers have various criteria, such as economic, social, technological, market, environmental, and time frame barriers. These barriers can be evaluated by the multi-criteria decision-making (MCDM) methodology. The MCDM methodology is employed to deal with various criteria and control them. The MCDM methodology is employed in the decision-making model with multiple criteria. The TOPSIS method is an MCDM method used in this paper to rank the alternatives under different criteria. The TOPSIS method is integrated with the spherical fuzzy set (SFS) to overcome the uncertainty in the evaluation process. This study used eight criteria and ten alternatives to be evaluated. The results show the economic criterion has the highest importance and social barriers have the lowest importance. Sensitivity analysis is employed in this study to show the stability of the results. The nine cases of sensitivity analysis are proposed, so the results show the rank is stable.

Keywords: Climate Change; Multi-Criteria Decision Making; Fuzzy Set; Decision Making Model; Uncertainty; Evaluation Problem.

1 | Introduction

The scholarly literature on changes to the existing and anticipated effects of climate change has grown significantly since the turn of the century. These studies have just begun to ask what social circumstances and characteristics prevent us from proactively adapting to environmental changes in the future [1-4]. Responses to these queries are sometimes called "barriers to adaptation." There are several explanations for the growing interest in adaptation obstacles. First, there are concerns about whether civilizations can adjust to climate change or are limited in some way, given the recent global catastrophes and the effects of climate change [5, 6].

Simultaneously, the focus of scientific conversations has switched from whether adaptation is necessary to how to adapt and what obstacles may exist for these adaptive attempts. Furthermore, the fourth IPCC

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https://doi.org/10.61356/j.mawa.2024.26661

assessment report provided a summary of the limitations and restrictions on climate change adaptation, which concluded that there were still substantial "research challenges to comprehending the processes by which changes are occurring and will occur in the future" [7-9]. Moreover, academic disciplines, including government, politics, sociology, geography, and psychology, have been more involved in the quickly developing discussions around climate change response [10, 11].

These social sciences provide fresh ideas, areas of interest for study, viewpoints, and approaches to evaluate many facets of adaptation, including obstacles to adaptation. Lastly, there have been more governmental measures for adaptation, which has produced a suitable substratum for conducting empirical case studies and analysing actual practice-based impediments [12-14].

Making decisions in an atmosphere of ambiguity and uncertainty is incredibly challenging. Making decisions in the face of this ambiguity and uncertainty has become more accessible, thanks mainly to the development of fuzzy set theory. Expert preferences are often articulated in language and measured using a Likert scale. However, since the Likert scale gives each linguistic phrase a single value, it cannot deal with the uncertainty or complexity of decision-making. Fuzzy set theory has made it possible to quantify language words using fuzzy numbers, which successfully capture the desired vagueness. Standard fuzzy sets, known as type-1 fuzzy sets, effectively capture ambiguity but must catch up when handling uncertainty. Therefore, fuzzy set theory has been extended in various ways by scholars to handle data uncertainty effectively.

Several criteria and trade-offs are present in real-world challenges and should be considered when making decisions. As a result, this kind of decision-making is known as multi-criteria decision-making (MCDM), which is further divided into many categories, including reference point, dominance, max-min, minimax, and comparative/relative measurement techniques.

Another MCDM technique that chooses the best option is the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). A choice is deemed optimal if it has the least distance from the best or most positive ideal outcome and the most significant distance from the worst or most negative perfect outcome [15-17]. When combined with TOPSIS, fuzzy set theory enables decision-makers to calculate more dependable results without making vagueness-related mistakes. Fuzzy TOPSIS is used in a variety of applications, such as assessing the functional compatibility of modern manufacturing equipment, examining the requirements for the implementation of reverse logistics in the Indian electronics industry, itemizing test cases to identify errors in software testing, evaluating flexible manufacturing system criteria, and looking into the variables influencing the length of time it takes to complete electrical installation projects [18, 19].

The three-dimensional fuzzy set known as the spherical fuzzy set (SFS), first presented by Kutlu Gündoğdu and Kahraman, was created as an extension of the intuitionistic fuzzy set, PFS, and the neutrosophic logics. Its primary purpose is to manage uncertainty while quantifying expert assessments. Historically, the mapping of various fuzzy set expansions (with a focus on spherical fuzzy evolution) [20-24]. This study used the spherical fuzzy set with the TOPSIS method to evaluate the barriers to climate change.

2 | Climate Policy Challenges

2.1 | Limited National Climate Regulations

Climate legislation faces many challenges from governments. To begin, many parties have not arrived at a decision about the most important topics. Climate law is an all-encompassing representation of the legislative needs of all relevant parties. However, many stakeholders have a range of different understandings of climate change, which results in a variety of legal expectations. Second, the impact of the government's ongoing efforts to restructure its institutions has not yet taken place. In addition, the institutional framework pertaining to climate change underwent restructuring, which necessitated the passage of sometime before legislation could be enacted. Third, the mechanism for climate management does not function perfectly. There are many nations that have accumulated expertise in a wide variety of systems, but there has only been little investigation into impact assessment systems, low-carbon technology catalog systems, and low-carbon production systems.

These systems need legislative backing and cooperation in order to function effectively. Last but not least, owing to the fact that climate policies span many different types of laws, it is difficult to separate climate legislation from other types of laws.

2.2 | Lack of Variety of Climate Policy Tools

Climate policies of nations can be categorized into three main types: command-and-control, market-based, and voluntary instruments. Command-and-control instruments encompass a range of mechanisms that are manifested in legal frameworks, regulatory frameworks, established standards, licensing systems, and quota systems. Market-based instruments play a crucial role in facilitating the achievement of climate targets by enhancing external circumstances through the implementation of a carbon tax, fostering technological advancements, and promoting international collaboration. Voluntary mechanisms serve as catalysts for encouraging individuals to engage in low-carbon practices by means of publicity, educational initiatives, and the shaping of public opinion. Nevertheless, it is important to acknowledge that various instruments possess both strengths and weaknesses. While the utilization of command-and-control instruments has the potential to result in information asymmetry, it is important to note that market-based instruments also require government oversight and encouragement. Voluntary instruments have the potential to diminish the coercive nature and urgency of policies, thereby resulting in a lack of success in attaining policy objectives. Therefore, it is imperative that these instruments are mutually reinforcing in order to generate synergistic outcomes.

2.3 | Poor Public Participation in Policymaking

Governance of the climate in certain nations is extremely centralized and dominated by authoritarianism. As a result of resource endowment, opportunity circumstances, and political effectiveness, several interest groups and the general public have been marginalized in the process of developing climate policy, which has made it difficult to participate in the negotiation of climate policy. When there is insufficient participation from the general population, it hurts the ability of governments and society to work together to accomplish their climate objectives. For instance, the climate policies of many nations are aimed towards governments at lower levels or businesses with a high emission intensity. To combat climate change, however, governments cannot do it on their own since doing so does not satisfy the needs of contemporary national governance. Ordinary people are put in a difficult situation when it comes to the implementation of policies that reduce emissions since there are not enough institutionalized avenues for public involvement. As a result, their demands about their interests cannot be voiced, and strong organizations control the policy process. In addition, both the uneven participation structure and the high-threshold negotiating network keep the general public out of the policymaking process. This, in turn, makes it easier for influential parties to hijack national interests and for interest groups to meddle with national autonomy. The administration of climate change mitigation must include collaboration between all levels of government and the general public. Boosting the transparency of the policy process, decreasing the obstacles to negotiation, and realizing cooperative governance are thus essential for the purpose of boosting the climate resilience of nations.

2.4 | Various Tradeoffs between the National and Local Administrations

Local governments are endowed with the ultimate authority in distributing policy resources, while central governments depend on local governments to implement the aims of their policies. This is also true for the governance of climate change in several nations, which suggests that the actions of local governments are the primary factor in determining whether or not climate targets are met. However, municipal administrations are not always responsive to their constituents' needs. In less developed areas, local governments have a tendency to allocate resources to short-term initiatives that create fast and visible economic output rather than long-term programs that provide steady and sustained economic progress. This is because short-term projects generate economic production more quickly and are more visible than long-term projects. According to the research of a number of academics, climate policies have the effect of retarding economic growth and causing economic loss in the near term. These negative effects are a direct consequence of the many choices that are made by central and local governments. There are a variety of perspectives on climate policy as a result of the many tradeoffs. The national government's overarching objective is to sustain long-term development; nevertheless, local governments choose one of three approaches. Local governments create action plans to pursue policies that optimize industrial structure but have no short-term economic rewards, but they do not devote resources to execute these action plans. Local governments use policies that optimize industrial structures and have immediate economic advantages in order to collect economic resources rather than to mitigate climate change. These policies have immediate economic benefits. Regarding the action plans that were developed to direct local governments in taking measures, local governments do not have much drive to put such plans into effect. Policy outcomes cannot be assured since various compromises must be made between the central government and local governments. When confronted with significant political pressure, local administrations may resort to unorthodox methods in order to accomplish their objectives.

3 | Methodology

A multi-criteria decision-making approach called TOPSIS determines which choice out of a range of possibilities is the most incredible fit. Hwang and Yoon industrialised it in 1981, and it is widely applicable in many fields, including engineering, commerce, and ecological research. TOPSIS helps decision-makers choose brands based on various attributes or criteria, weighing each option against these standards [25-27]. This section introduces the steps of the SF-TOPSIS method. The SF is integrated with the TOPSIS method to rank the alternatives. Figure 1 shows the steps of the suggested methodology.

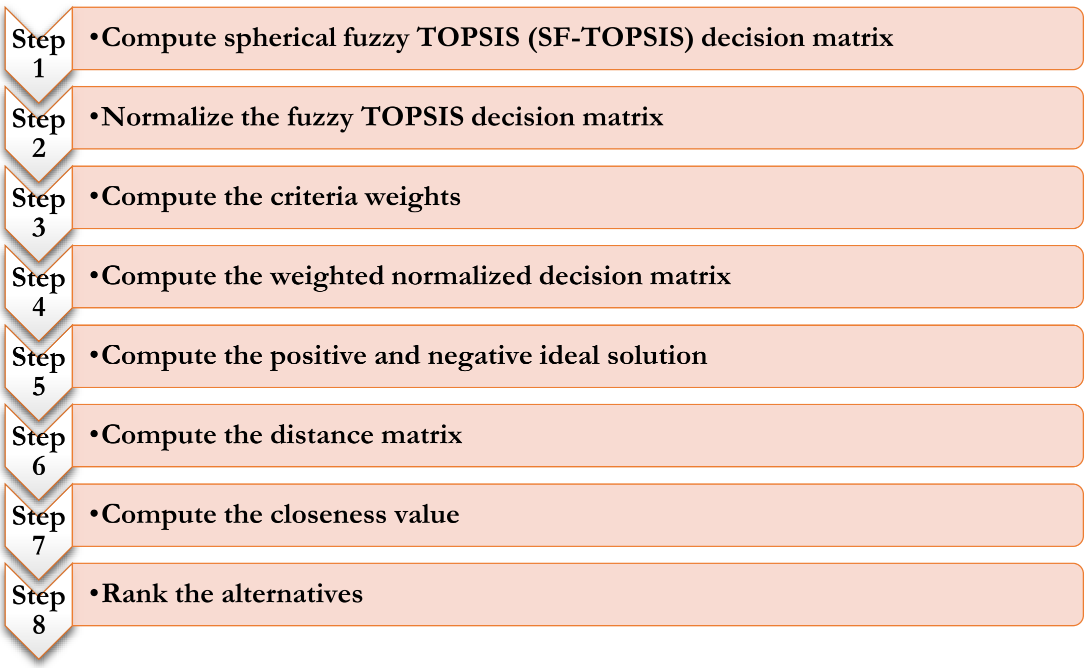

Figure 1. The steps of the SF-TOPSIS method.

Step 1. Compute spherical fuzzy TOPSIS (SF-TOPSIS) decision matrix.

The decision matrix is computed based on the criteria and alternatives. The evaluation of criteria and alternatives are evaluated by the experts as Table 1. The experts and decision makers used the spherical fuzzy linguistic variables as shown in Table 2. Then we used the spherical fuzzy numbers to evaluate the criteria and alternatives.

Step 2. Normalize the fuzzy TOPSIS decision matrix using Eq. (1).

$$N_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n}\left(x_{ij}\right)^2}} \tag{1}$$

Step 3. Compute the weighted normalized decision matrix.

$$r_{ij} = w_j N_{ij} \quad (2)$$

Step 4. Compute the positive and negative ideal solution

$$a_i^* = (a_1^*, a_2^*, \dots . a_m^*) \quad (3)$$

$$a_i^* = \max w_j N_{ij} \quad (4)$$

$$a_i^- = (a_1^-, a_2^-, \dots . a_m^-) \quad (5)$$

$$a_i^- = \min w_j N_{ij} \quad (6)$$

Step 5. Compute the distance matrix.

The distance matrix is computed from each alternative as:

$$T^* = \sqrt{\sum_{i=1}^{m} (w_j N_{ij} - a_i^*)} \quad (7)$$

$$T^- = \sqrt{\sum_{i=1}^{m} (w_j N_{ij} - a_i^-)} \quad (8)$$

Step 6. Compute the closeness value

$$U_i = \frac{T^-}{T^- + T^{*s}} \quad (9)$$

Table 1. Information about consultants.

Consultants	Experience (Years)	Occupation	Profession	Academic degree
Consultant$_1$	10	Industry	Climate Change and Environment Manager	Ph.D.
Consultant$_2$	15	Academia	GHG and Environmental Analyst	Ph.D.
Consultant$_3$	10	Industry	Global climate advisor	Ph.D.

Table 2. Semantic terms and corresponding SFNs for evaluating criteria and alternatives.

Semantic terms	Abbreviations	Spherical fuzzy numbers		
		μ	υ	π
Quite weak importance	UWM	0.10	0.90	0.10
Very weak importance	VWM	0.20	0.80	0.20
Weak importance	WEC	0.30	0.70	0.30
Slightly weak importance	SWP	0.40	0.60	0.40
Evenly importance	EVM	0.50	0.50	0.50
Slightly high importance	SHM	0.60	0.40	0.40
High importance	HGM	0.70	0.30	0.30
Very high importance	VGM	0.80	0.20	0.20
Quite high importance	HMP	0.90	0.10	0.10

4 | Application

This section introduces the results of SP-TOPSIS to evaluate the barriers of the climate change. The criteria of barriers in climate change are shown in Figure 2.

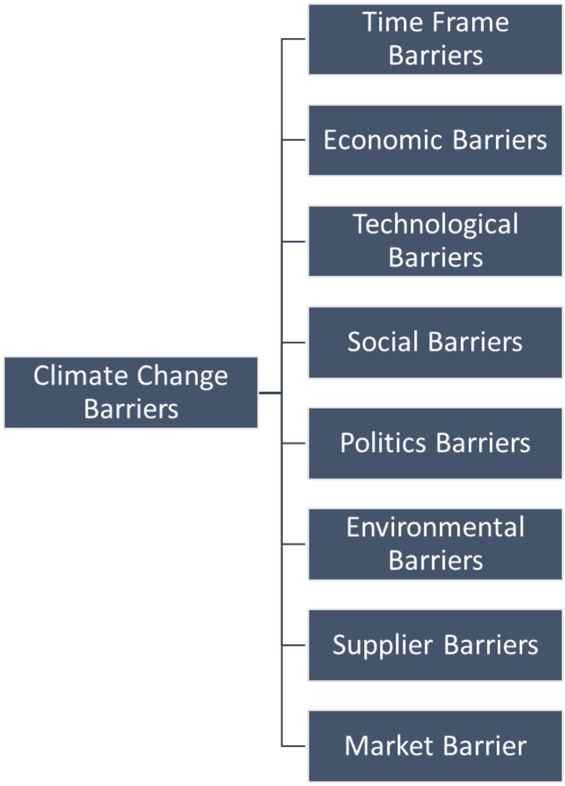

Figure 2. The barriers of climate change.

Step 1. Compute spherical fuzzy TOPSIS (SF-TOPSIS) decision matrix.

The experts and decision makers evaluated the criteria and alternative by their linguistic variables. Then we replace these variables by the spherical fuzzy numbers (SFNs).

Step 2. Normalize the fuzzy TOPSIS decision matrix. The normalized decision matrix is computed by Eq. (1) as shown in Table 3.

Table 3. The normalized decision matrix.

	CLM_1	CLM_2	CLM_3	CLM_4	CLM_5	CLM_6	CLM_7	CLM_8
$CLMA_1$	0.122553	0.301305	0.384602	0.261193	0.142242	0.140773	0.318546	0.305335
$CLMA_2$	0.187984	0.301305	0.253781	0.315319	0.291239	0.28941	0.319034	0.254124
$CLMA_3$	0.328192	0.363742	0.295329	0.261193	0.34993	0.287596	0.318546	0.174891
$CLMA_4$	0.273147	0.362024	0.354844	0.315319	0.291239	0.347534	0.47049	0.254124
$CLMA_5$	0.355715	0.258916	0.295329	0.478192	0.361003	0.289245	0.256986	0.465249
$CLMA_6$	0.32975	0.301305	0.295329	0.290987	0.289578	0.347534	0.31024	0.254124
$CLMA_7$	0.494366	0.363742	0.356529	0.282545	0.5332	0.287596	0.220832	0.475878
$CLMA_8$	0.273147	0.37348	0.295329	0.313829	0.20431	0.52955	0.308774	0.218372
$CLMA_9$	0.328192	0.301305	0.183037	0.32376	0.291239	0.347534	0.318546	0.305335
$CLMA_{10}$	0.324557	0.186167	0.390217	0.261193	0.250266	0.067637	0.256986	0.314031

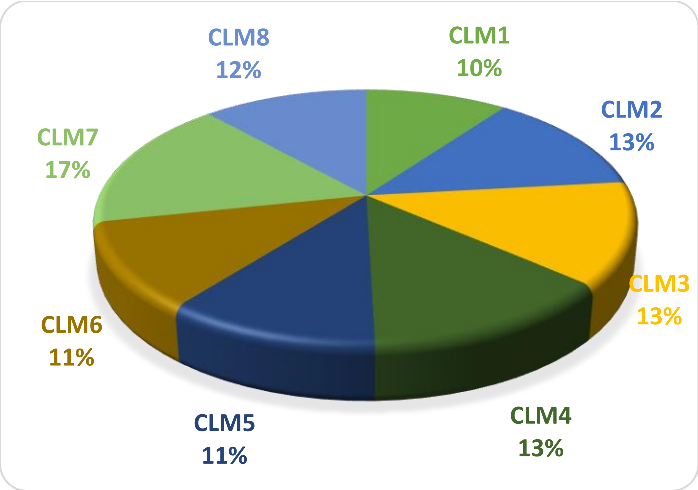

Figure 3. The criteria weights.

Step 3. Compute the weighted normalized decision matrix by Eq. (2) as shown in Table 4.

Table 4. The weighted normalized decision matrix.

	CLM_1	CLM_2	CLM_3	CLM_4	CLM_5	CLM_6	CLM_7	CLM_8
$CLMA_1$	0.012272	0.039845	0.050334	0.034585	0.015743	0.015552	0.053042	0.035624
$CLMA_2$	0.018824	0.039845	0.033213	0.041752	0.032234	0.031972	0.053123	0.029649
$CLMA_3$	0.032864	0.048102	0.03865	0.034585	0.03873	0.031772	0.053042	0.020405
$CLMA_4$	0.027352	0.047874	0.046439	0.041752	0.032234	0.038394	0.078343	0.029649
$CLMA_5$	0.03562	0.034239	0.03865	0.063318	0.039956	0.031954	0.042791	0.054282
$CLMA_6$	0.03302	0.039845	0.03865	0.03853	0.03205	0.038394	0.051659	0.029649
$CLMA_7$	0.049504	0.048102	0.04666	0.037412	0.059014	0.031772	0.036771	0.055522
$CLMA_8$	0.027352	0.049389	0.03865	0.041555	0.022613	0.058502	0.051415	0.025478
$CLMA_9$	0.032864	0.039845	0.023954	0.04287	0.032234	0.038394	0.053042	0.035624
$CLMA_{10}$	0.0325	0.024619	0.051068	0.034585	0.027699	0.007472	0.042791	0.036639

Step 4. Compute the positive and negative ideal solution by Eqs. (3)-(6).

Step 5. Compute the distance matrix by Eqs. (7) and (8).

Step 6. Compute the closeness value by Eq. (9) as shown in Figure 4.

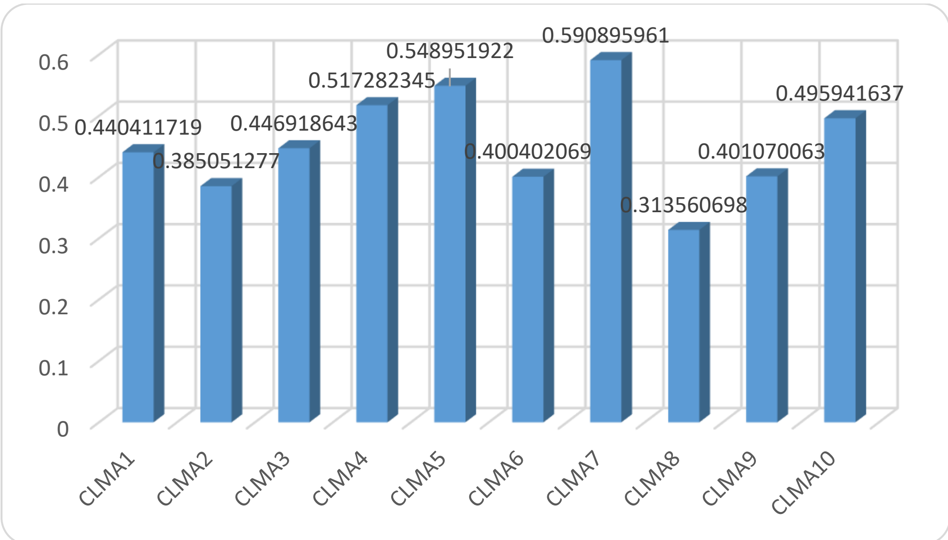

Figure 4. The values of closeness of SF-TOPSIS method.

The results show that alternative 7 is the best and alternative 8 is the worst using the SF-TOPSIS method under different criteria weights using the average method. The results show that the economic criterion has the most significant weight, and the social criterion has the lowest. This study used the opinions of experts and decision-makers to evaluate the requirements and alternatives. Then, their opinions are replaced by the spherical fuzzy numbers. The SF is used to overcome the uncertainty and vague information in the evaluation process. This study used eight criteria and ten alternatives of barriers to climate change.

This study conducted a sensitivity analysis to show the different ranks of alternatives under different criteria weights. This study proposed nine cases of criteria weights changing. In the first case, we proposed that all criteria have the same weight. In the second case, we proposed the first criterion has 0.16 weight and other criteria have the same weight (0.12). In the third case, the second criterion has 0.16, and all other criteria have the same weight and so on, as shown in Figure 5.

We used these cases to enter them in the SF-TOPSIS method. There are nine ranks in the SF-TOPSIS under nine instances. Figure 6 shows the different ranks of alternatives. The results show that all ranks are stable under different cases.

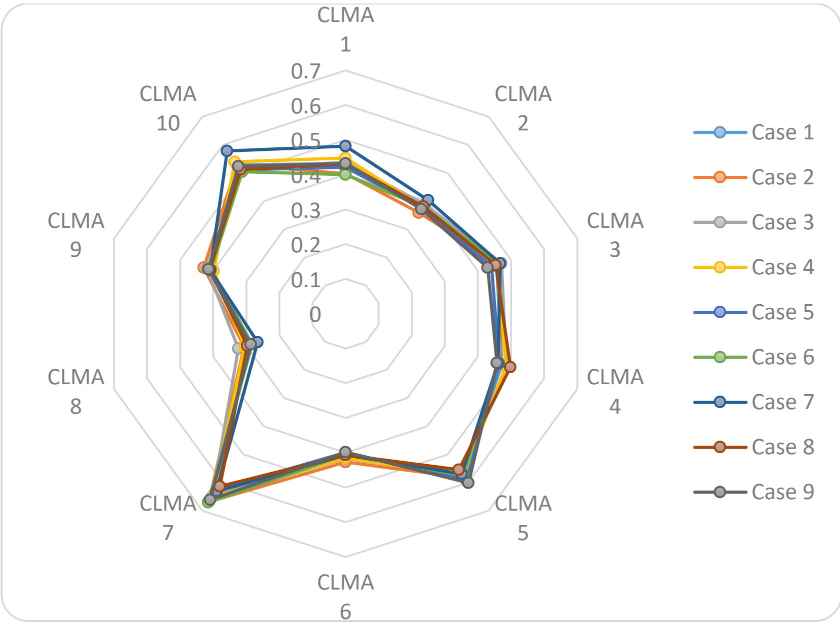

Figure 5. The values of closeness under different cases.

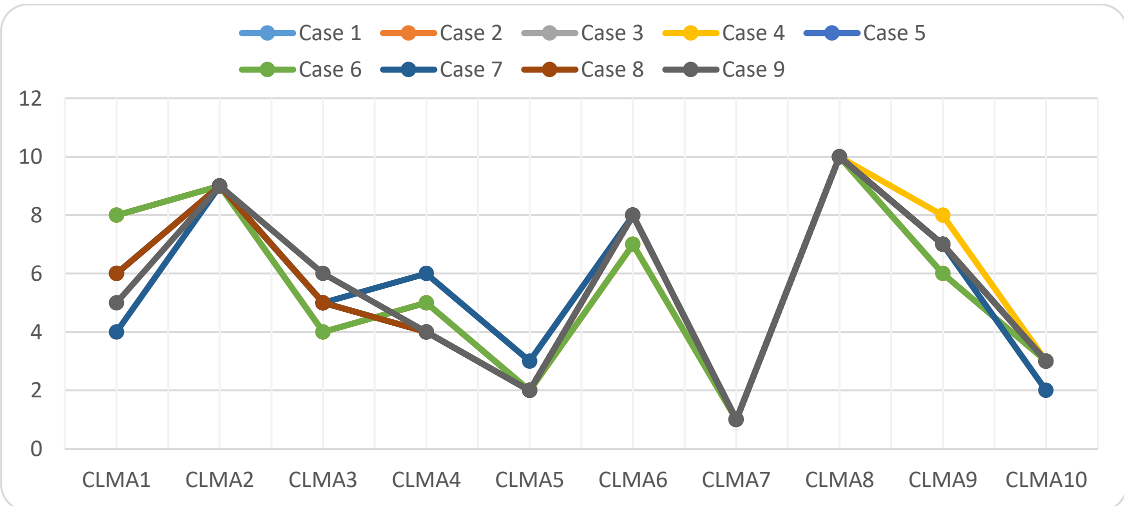

Figure 6. The rank of alternatives under different cases.

5 | Conclusions

This study used an MCDM methodology to evaluate the barriers to climate change. The experts and decision-makers evaluated the criteria and alternatives to building the decision matrix. The spherical fuzzy numbers change these opinions. The spherical fuzzy TOPSIS is used in this study to rank the other options. The SF is used to overcome vague and uncertain information. The TOPSIS method has the positive and negative ideal solutions between criteria. The eight criteria and ten alternatives are used in this study. The results show that alternative 7 is the best and alternative 8 is the worst. The sensitivity analysis evaluates these results. The nine cases of changing the criteria weights are proposed. The results show the rank under different cases is stable.

Acknowledgments

The author is grateful to the editorial and reviewers, as well as the correspondent author, who offered assistance in the form of advice, assessment, and checking during the study period.

Author Contributaion

All authors contributed equally to this work.

Funding

This research has no funding source.

Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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