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Neutrosophic Multi-Criteria Decision-Making for Flood Risks Management: A Comprehensive Analysis

Abdullah Ali Salamai
Applied College, Jazan University, Jazan, Kingdom of Saudi Arabia
Email: abSalamai@jazanu.edu.sa

Abstract

The terrible consequences that floods are having on human life and property can be seen all around the globe. The flood risks management problem is subject to uncertain and imprecise data, and it is influenced by several different factors. As a result, the assessment procedure in question might be seen as an instance of a challenging uncertain multi-criteria decision-making (MCDM) issue. Within the context of single-valued neutrosophic sets (SVNSs), this research aims to present a novel integrated methodology that is based on the Combined Compromise Solution (CoCoSo) technique under a neutrosophic environment. Both the decision-makers and the weights of the criteria are completely unknown. The average technique is used in the proposed methodology to calculate the weighting of the criteria, and an updated version of the CoCoSo method is used within the context of the SVN to decide which option is the most appropriate. In addition, an example case study of flood risk management is explored to highlight the entire execution process of the suggested technique. In addition, a comparison with other approaches that already exist is described to evaluate the validity of the results that were achieved.

Keywords: Risk Management; Flood; MCDM; Neutrosophic; single-valued neutrosophic

1. Introduction and Literature Review

In coastal and inland parts of the United States that are affected by high monsoon rains, flooding is responsible for considerable losses of human life, which in turn results in severe socio-economic repercussions. Because they may inundate places with little to no advance notice, flash floods pose an especially grave threat. Floods have the potential to hasten the process of erosion and landslides, both of which may result in abrupt morphological changes in the region. Floods also influence the geo-environment because they may carry harmful industrial wastes and chemicals, which can pollute surface and subsurface water as well as farm areas. This is another way that floods have an impact on the environment[1], [2].

Across the course of the previous two decades, there has been a more than 40% rise in the frequency of floods all over the globe. Over 109 million individuals were impacted by floods between the years 1995 and 2015, with losses reaching up to $75 billion per year in the United States. Floods can have both human-caused and natural reasons, with global warming being regarded as one of the principal factors for adjustments in flood trends, severity, and magnitude. Floods can occur anywhere from a few inches to several feet of water. The 1931 Central China flood, which occurred in China, was the natural catastrophe that claimed the most lives in the 20th century. China is only one of the many nations in Asia that are severely impacted by flooding. It is believed that 3.7 million people perished as a direct result of this catastrophe. Flooding rivers in China were responsible for an estimated $51 billion in yearly damages in 2010, according to estimates. Rainfall patterns in China are shifting during the last several years, which has resulted in greater precipitation between April and June. The increased precipitation has resulted in flooding across a significant portion of Ningdu County. Alterations in the patterns of rainfall have been linked, in general, to a rise in anthropogenic activities,

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which have been considered to be directly to blame for a rise in the number of times that flooding occurs[3]–[5].

Floods, because of the damage they do to human life, may have a significant influence on the economical well-being of an area. In light of this, the right measures essential to be occupied to decrease the risk of flooding[6]. When attempting to anticipate the many diverse features of flood occurrences, several alternative methodologies have been tried. One of the earliest methods that were attempted was to establish a statistical association between the features of floods and the physical qualities of watersheds. In various regions across the globe, more recently, conceptual and physically-based models have been utilized for flood prediction. Nevertheless, the production of flood maps continues to be a difficult task[7]–[9].

Because watersheds are inherently complex, floods cannot be simulated by simple nonlinear models because of their complexity. In the latest days, however, data-driven methods such as multi-criteria decision-making (MCDM), multivariate statistical models, and bivariate statistical models have become more prevalent.

The use of (MCDM) techniques may be advantageous to the process of flood risk management. The phrase MCDM is an umbrella word that is used to represent a range of approaches for organizing and assessing potential solutions based on several different criteria and goals. The inherent complexity and ambiguity of such situations are handled by these approaches, and the information that results from the engagement of several players is accounted for. As a result, these techniques give judgments that are targeted.

MCDM can improve the quality of decisions by making the decision-making process more clear, logical, and efficient, which ultimately results in choices that can be justified and explained. In addition to this, MCDM encourages participants to show an active role in the policymaking procedure, makes it easier for groups to reach compromises and conclusions, and offers an appropriate forum for stakeholders to convey their preferences. The mixture of these traits makes it possible to build genuine participatory procedures, which are essential for the effective and sustainable implementation of flood control programs.

Consequently, MCDM is a useful tool for flood management and has obtained a significant amount of interest in the solving of such issues, not only from scholars but also from decision-makers and specialists outside of the science establishment. This is because MCDM provides an effective solution to the problem of flooding. Since the middle of the 1990s, MCDM has been effectively implemented to pick the best techniques for flood risk reduction, contributing to the optimization of the use of available resources. This has helped to improve overall resource utilization. In recent years, MCDM has also been used to assess the danger of flooding and the ability of the community to cope with it.

Some scholars have written reviews on MCDM approaches in a variety of academic subjects. For instance, Stewart carried out a theoretical evaluation by determining the possible benefits and drawbacks associated with the use of a variety of MCDM methodologies. In the subject of water resource planning and management, Hajkowicz and Collins examined more than 134 publications, concentrating on issues such as water policy assessment, strategic planning, and construction selection. More lately, Estévez and Gelcich provided a condensed literature assessment that explored the difficulties associated with participatory marine conservation data management.

The capabilities of cities to deal with the effects of flooding and recover from those effects is a key component that is measured by urban flood resilience, which is a key assessment. In the context of flood risk management, the evaluation of flood resilience can be viewed as an MCDM problem; this is because it is regarded as being essential for assisting decision-making. Because various MCDM techniques would produce varying assessment results, Zhu and Liu[10] suggested a method for group decision-making that is composed of three phases, notably, the normalization of data, the determination of weights, and the agglomeration of results. To accomplish the goal of MCDM, the proposed framework incorporates various methods. When applied, SMAA-2 takes into account all possible desires among the various MCDM methods to produce results that are suitable for holistic evaluation. To demonstrate the usefulness and reliability of our technique, a case study focusing on the Yangtze River is obtainable here. They utilized four Methodologies; however, the structure can accommodate different techniques that can be objective, subjective, or even merged. The techniques can also be combined. They anticipated that researchers will apply the methodological approach to other issues about the management of natural disasters. Furthermore, the value of the criteria may be

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uncertain when applied in practice; such ambiguity of criteria may be something that is taken into consideration by subsequent research. Since only 41 options with 17 factors are assessed.

It is essential to provide a guarantee for the management of assets in terms of the expected rate of return on investments throughout their anticipated life cycle. Therefore, risk perception for properties and capital ventures may be implemented during the planning and design phases, and this may be linked with effective management that is structured following a risk group. In particular, natural disasters pose a significant danger to both the integrity of the infrastructure and even the lives of people. It is thus unavoidable to attempt to evaluate flood dangers in vulnerable zones throughout the country. In the research carried out by Hüseyin Akay[11], a study region that was often exposed to flash flood risks was selected. Furthermore, flood risk data and flood precondition variables of the research region were combined using a GIS-based technique to produce flood hazard vulnerability maps. As a result of the fact that the techniques need the interpreting and data to be processed, it is not only necessary but also difficult to decide on the method, the data, and how these three things will be combined. To develop flood risk susceptibility maps, many different approaches including FR, EBF, WoE, and IoE, as well as a hybrid combination of PCA, FL, AHP, TOPSIS, and VIKOR, were used. Using sensitivity, specificity, accuracy, kappa index, the area under the curve (AUC), and SCAI, he developed flood risk susceptibility maps. These maps were then verified for use with both testing and training data sets. While some of the strategies produced highly satisfying outcomes, others produced results that were less than satisfying. Because the results of all of the statistical tests did not lead in the same way, a straightforward strategy was used to determine which method was the most acceptable. PCA and AHP approaches were shown to be more accurate in predicting flood risk susceptibility mapping with ROC analysis and SCAI variation. This was the conclusion drawn from the findings.

Tella and Balogun [12]conducted research on the elements that contribute to flooding in the city of Ibadan and produced a geographical flood susceptibility model by combining two multi-criteria decision-making (MCDM) approaches with GIS. Because it is one of the major cities in West Africa, the research region was selected because it has a long history of catastrophic floods that have had a negative influence on a great number of people's lives as well as their assets. Because of the association between each of these ten parameters and floods in the research region, they were chosen as potential causes. According to the findings of the AHP and FAHP systems, the three factors that have the greatest influence on the likelihood of flooding are rainfall, runoff, and distance from streams. The components of the study location that are positioned in the south, northeast, and adjacent areas have very high and especially vulnerable flood hazard zones. On the other hand, the parts of the research site that are situated in the north and some parts of the southwest have been categorized as low likely to succumb regions with very little chance of flood hazardous event. The models were evaluated by superimposing the locations of historical flood occurrences on the maps that were created. A comparative evaluation revealed that the FAHP performed much better than the AHP. According to the FAHP model, the majority of the historical flood occurrences fall into relatively high flood hazard zones. However, according to the AHP model, a large number of historical flood events fall between high to medium flood hazard zones. In the context of the AHP flood map, none of the historical flood records fell into the extremely highly vulnerable category. The combined spatial MCDM systems may, thus, be used for essential parameters of flood susceptibility maps that are capable of sensitizing stakeholders, notably experts and people, on flood occurrences, hence increasing the effectiveness of flood mitigation and adaptation strategies. The administration and all other relevant parties should devote a greater amount of time and energy to ensuring that the city is well-planned. New projects should be placed in areas that are apart from streams, and drainages should be kept in good condition to ensure that rainwater may flow freely through them. In addition, homeowners should be educated about the factors that might lead to flooding as well as the correct preventative steps to take. In addition, those who throw garbage in the stream, which clogs up the drainage system, need to be subject to financial penalties.

Although conventional methods of decision-making are incapable of handling the processing of ambiguous information. In this respect, the concept of the fuzzy set (FS) has served as a source of motivation for scholars all over the world due to the adaptability and efficiency with which it deals with scenarios in which the information that is accessible is either imprecise or partial. Atanassov is credited with pioneering the concept of the intuitionistic fuzzy set (IFS), which serves as a generalization of fuzzy sets (FSs). Zadeh's approach to FS is not as suitable for dealing with vagueness and ambiguity as Atanassov's IFS.

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Nevertheless, the notions of FSs and IFSs can only handle data that is either missing or unclear; they cannot deal with information that is either inconsistent or ambiguous, which is typical in real-world scenarios. Smarandache came up with the idea of the neutrosophic set (NS) to improve the accuracy of the management of such information. NS is a potent generic formal framework that reduces the aforementioned sets from a philosophical point of view. It is a component of neutrosophy, the study of the genesis, nature, and extent of neutralities, in addition to their interactions with other ideational spectra[13], [14]. The word "neutrosophy" incomes "information of a neutral mind," and the word "neutral" serves as a symbol for the primary difference that can be made between first- and second-order logic. NS is distinguished by the presence of three separate membership functions that, respectively, represent the functions of truth, indeterminacy, and falsehood[15], [16].

This work proposes a combined MCDM technique for handling the multi-criteria flood risk assessment issue under a single-valued neutrosophic sets (SVNs) context. This approach was inspired by the notion of SVNSs and was developed as part of this study[17]. The assessment of the criterion weights and the prioritizing of the alternatives are two procedures that are crucial for the decision-makers to do while confronting difficulties with MCDM. As a result of the difficult decision contexts and the limited familiarity of DMs, the information about the criterion weights is often entirely unknown[18], [19]. The CoCoSo (combined compromise solution) technique is one of the recently created ways that allows the DMs to rate the options using a variety of qualitative and quantitative criteria. In terms of the ordering of possibilities, it has a high level of dependability and consistency[20]–[24].

In light of the conversations that have taken place so far, the current investigation builds upon the CoCoSo approach to a single-valued neutrosophic situation to provide an combined MCDM outline to assess flood risk options.

The following is an outline of the most important contributions made by this study:

i. Combining the CoCoSo technique with the SVNS idea resulted in the creation of an innovative decision-making process.
ii. The COCOSO-based technique is presented here so that the weights of the criteria may be determined.
iii. To determine whether or not the approach that has been presented is applicable, it is applied to an empirical case study that involves flood risk management and contains information that is ambiguous, imprecise, and inconsistent.

2. Material and Methods

2.1 Preliminary Terms

Smarandache is credited with having first conceptualized the idea of NS. In NS, every component has a grade of indeterminacy in addition to the levels of membership and nonmembership. This is because the DMs are not always familiar with the elements that are associated with the policymaking process, and each of the functions is self-reliant in its very nature. For instance, if we ask a customer what they think about a certain assertion, the customer may respond that the likelihood of agreeing to the assertion is 0.8, the possibility of disagreeing with the assertion is 0.1, and the potential of not being sure is 0.2. It may be expressed as (0.8, 0.1, 0.2) in an NS, but it cannot be handled by an IFS since the total of the values for membership, non-membership, and reluctance is not 1.

***Definition* 1**

Let's say that a collection of items denoted by the notation $X = x_1 \ , x_2, \dots, x_m$ constitutes what is known as a universal set. The membership function of a NS is characterized by having three dimensions or grades, such as a truthness grade $T_M(x_i)$, an indeterminacy grade $I_M(x_i)$, and a falsehood grade $F_M(x_i)$. A NS M in X is an example of this kind of set (x_i).

Real standard or nonstandard subsets of]-0, 1+[may be found in the functions $T_M(x_i)$, $I_M(x_i)$, and $F_M(x_i)$, respectively.

NS may be understood in terms of mathematics as

$$M = \{(x_i, T_M(x_i), I_M(x_i), F_M(x_i)) | x_i \in X\} \qquad (1)$$

Where $T_M(x_i) \to] - 0,1 + [, I_M(x_i) \to] - 0,1 + [, F_M(x_i) \to] - 0,1 + [$ there no limitation in sum of $T_M(x_i), I_M(x_i), F_M(x_i)$, where $0 \leq \sup\ (T_M(x_i)) + \sup\ (I_M(x_i)) + \sup\ (F_M(x_i)) \leq 3$

The foundation of NS is a philosophical idea, which makes it difficult to digest during engineering applications and much more difficult to adapt to real-world scenarios. As a result, Wang et al. came up with the concept of SVNSs and had it defined by Z as a universal set consisting of a finite set of elements. During the decision-making process, these elements are considered to have subjective rating values according to the Likert scale, such as great, negative, ordinary, greater, poor, and so on. Every of these rating aspects inside the universe of data generated for policymaking has a grade that corresponds to it, and those grades are either membership, non-membership, or uncertainty.

Definition 2

Let us suppose that X is a complete universal set and that x_i is one of X's generic elements. A SVNS V in X is described by a truth membership task $t_V(x_i)$, an indeterminacy membership task $i_V(x_i)$, and a falsity membership function $f_V(x_i)$, where the truth, indeterminacy, and falsity membership task are all real subsets of [0,1].

$$V = \{(x_i, t_V(x_i), i_V(x_i), f_V(x_i)) | x_i \in X\} \tag{2}$$

Where $t_V(x_i) \rightarrow [0,1], i_V(x_i) \rightarrow [0,1], f_V(x_i) \rightarrow [0,1]$ and the sum of $t_V(x_i), i_V(x_i), and\ f_V(x_i)$ Are in [0,3]

$$0 \leq t_V(x_i) + i_V(x_i) + f_V(x_i) \leq 3 \tag{3}$$

Definition 3

Let $A = (t_1, i_1, f_1), B = (t_2, i_2, f_2)$ are two SVNNs and their operation are:

$$A^c(f_1, 1 - i_i, t_1) \tag{4}$$

$$A \cup B = (\max(t_1, t_2), \min(i_1, i_2), \min(f_1, f_2),) \tag{5}$$

$$A \cap B = (\min(t_1, t_2), \max(i_1, i_2), \max(f_1, f_2),) \tag{6}$$

$$A \oplus B = (t_1 + t_2 - t_1 t_2, i_1 i_2, f_1 f_2) \tag{7}$$

$$A \otimes B = (t_1 t_2, i_1 + i_2 - i_1 i_2, f_1 + f_2 - f_1 f_2) \tag{8}$$

Definition 4

Let the $A = (t_1, i_1, f_1)$ be a SVNN. Compute the score function as:

$$R(A) = \frac{2 + t_1 - i_1 - f_1}{3}; R(A) \in [0,1] \tag{9}$$

Definition 5

The SVN weighted athematic and geometric can be computed as:

$$WA = \bigoplus^{m}(A, w) = \left(1 - \prod_{i=1}^{m}(1 - t_i)^w, \prod_{i=1}^{m}(1 - i_i)^w, \prod_{i=1}^{m}(1 - f_i)^w, \right) \tag{10}$$

$$WG = \otimes^m (A, w) = \left(\prod_{i=1}^{m}(1 - t_i)^w, 1 - \prod_{i=1}^{m}(1 - i_i)^w, 1 - \prod_{i=1}^{m}(1 - f_i)^w, \right) \tag{11}$$

Definition 6

The distance between two SVNNs can be computed as

$$D(A, B) = \frac{1}{3m}\sum_{i=1}^{m}(|t_A(x_i) - t_B(x_i)| + |i_A(x_i) - i_B(x_i)| + |f_A(x_i) - f_B(x_i)|) \tag{12}$$

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The CoCoSo technique is an innovative new approach to MCDM that was first developed by Yazdani et al. This technique has found widespread use in a variety of domains, including the evaluation of green development indicators, the selection of WEEE recycling partners, and other areas. For example, it has been utilized in the assessment of medical waste treatment systems. Figure 1 shows the steps of the proposed methodology.

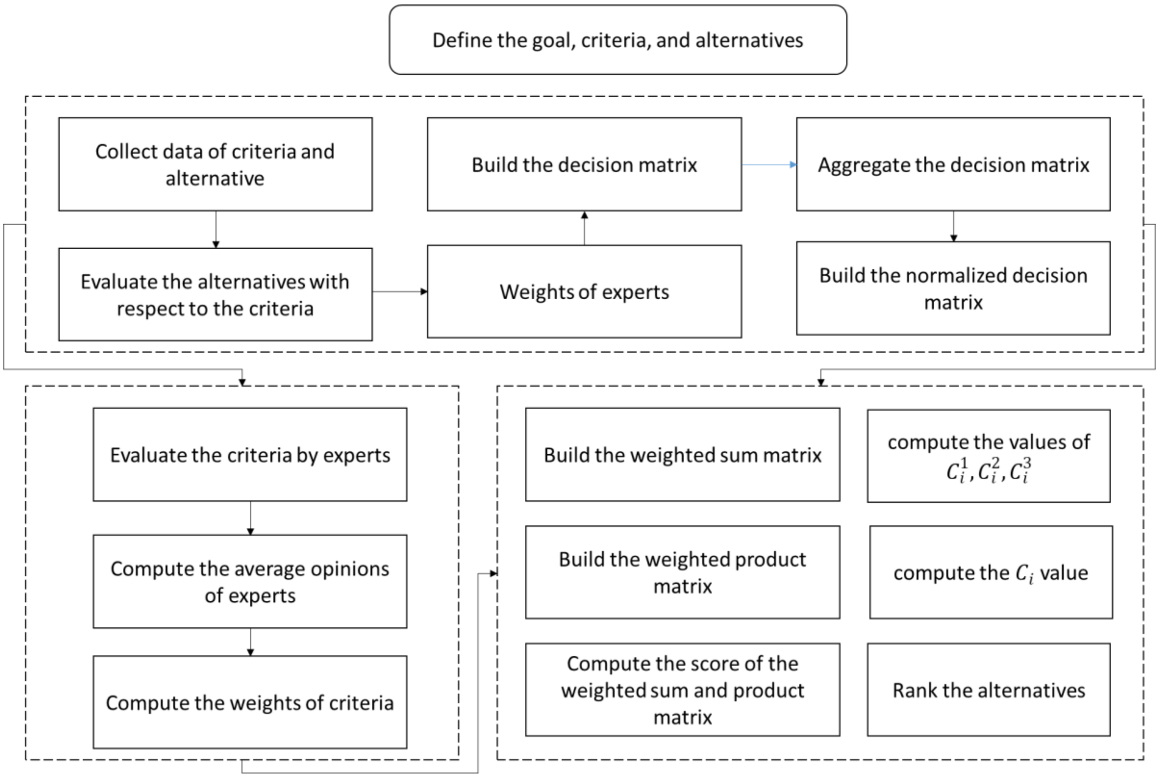

Figure 1:The stages of the suggested procedure.

The creation of the decision matrix begins with the construction of a panel of decision-makers denoted by the notation. This panel's purpose is to evaluate the efficacy of a set of options or alternatives denoted by the notation concerning a set of criteria denoted by the notation.
Consider the fact that each evaluator belonging to the DMs' group provides the evaluation information of each option employing criteria expressed in the form of linguistic Values.

A compilation of many decision-making perspectives
Constructing an averaged SVN decision matrix requires combining all of the individual preferences of DMs into a single opinion during the MCDM process that involves more than one expert.

$$AG = \left(1 - \prod_{i=1}^{m}(1 - t_i)^w, \prod_{i=1}^{m}(1 - i_i)^w, \prod_{i=1}^{m}(1 - f_i)^w, \right) \quad (13)$$

Create the aggregated decision matrix that has been normalized.
It is necessary to normalize the A-SVN-DM that was provided by the step before this one to manage both the non-beneficial and advantageous sorts of criteria.

Compute the weights of the criteria

As the CoCoSo methodology develops with the integration of the additively simple weighted and exponentially weighted product models, the phrase "as the CoCoSo methodology develops." As a result, to locate the weighted sum Q_i^1 and the weighted product sequences Q_i^1

$$Q_i^1 = \bigoplus^{n} w_j AG_{ij} \quad (14)$$

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$$Q_i^2 = \bigotimes^{n} w_j AG_{ij} \tag{15}$$

The relative values of the options are determined by using three different assessment score methodologies, which are described as follows:

$$C_i^1 = \frac{Q_i^1 + Q_i^2}{\sum_{i=1}^{m}(Q_i^1 + Q_i^2)} \tag{16}$$

$$C_i^2 = \frac{Q_i^1}{\min\limits_i Q_i^1} + \frac{Q_i^2}{\min\limits_i Q_i^2} \tag{17}$$

$$C_i^2 = \frac{\alpha Q_i^1 + (1-\alpha) Q_i^2}{\alpha \max\limits_i Q_i^1 + (1-\alpha) \max\limits_i Q_i^2} \tag{18}$$

The ultimate ranking of the options is determined by aggregating a compromise index, which is based on the logical integration of three scores.

$$C_i = (C_i^1 C_i^2 C_i^3)^{\frac{1}{3}} + \frac{1}{3}(C_i^1 + C_i^2 + C_i^3) \tag{19}$$

The greater the levels of Ci, the more desirable the choices become.

3. Implementation

The term "flood risk" refers to a recurrent hydrological phenomenon that has been examined in this research as well as previous studies of flood crisis management that are quite comparable. In the meanwhile, statistical functions provide the basis for the interpretation of precipitation and other meteorological events. As a consequence of this, the occurrence of an event in the past is taken into consideration as a signal when evaluating an event that is now taking place.

There are six criteria in this study namely, Politics, economic, social, technological, ecological, legal, and 15 alternatives. Let experts evaluate the criteria and alternatives as shown in table 1 in the appendix. The decision matrix between six criteria and 15 alternatives. Then utilize the COCOSO steps to rank and select the best alternatives. The weights of criteria are computed and the outcomes are w1 = 0.0645, w2 = 0.193, w3=0.096, w4=0.225, w5=0.258. w6=0.161. From the outcomes of weights in six criteria, criterion 5 is the uppermost rank and standard 1 is the lowest importance in six criteria.

Then use the decision matrix in table 1 in the appendix then normalize the decision matrix as shown in table 1. Then compute the weighted sum matrix and weighted product matrix as shown in tables 2, and 3 in the appendix. Then compute the values of C_i^1, C_i^2, C_i^3 as shown in table 2. Figure 2 shows the values of C_i^1, C_i^2, C_i^3. Then compute the C_i as shown in table 3. Figure 3 shows the value of C_i. From figure 3 FA$_3$ is the best alternative and FA$_7$ is the nastiest substitute.

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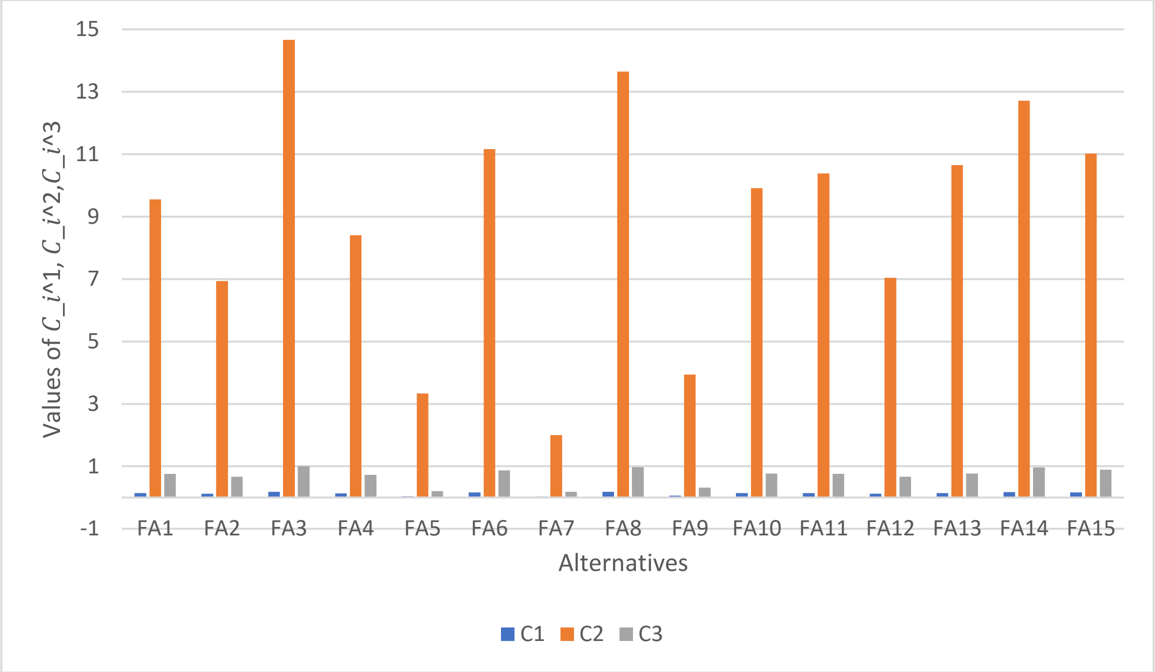

Figure 2: The values of C_i^1, C_i^2, C_i^3

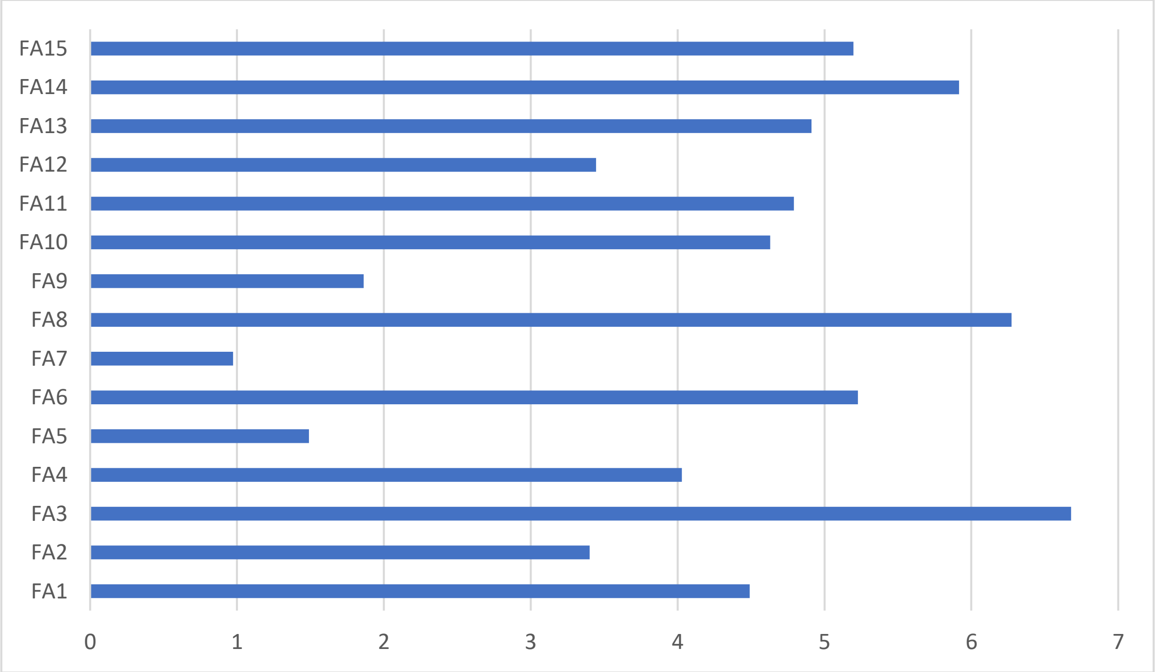

Figure 3: The value of C_i

Table 1: The normalization decision matrix.

	FC$_1$	**FC$_2$**	**FC$_3$**	**FC$_4$**	**FC$_5$**	**FC$_6$**
FA$_1$	1	0	0.833333	0	1	0.857143
FA$_2$	0.857143	0	0.5	0.857143	0	0.142857
FA$_3$	0	1	1	1	1	1
FA$_4$	0.857143	1	0.5	0	0	0.857143
FA$_5$	0	0	0	1	0	0
FA$_6$	0.142857	1	0	0.857143	0.857143	0.142857
FA$_7$	0	0	1	0	0	0
FA$_8$	1	1	0	1	0.857143	0.857143

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FA_9	0	0	0	0.857143	0	0.142857
FA_{10}	1	1	1	0	0.857143	0
FA_{11}	0.142857	0	0	1	1	0.857143
FA_{12}	1	0	0.5	0.857143	0	0.142857
FA_{13}	1	0	0	1	0.857143	0.857143
FA_{14}	0.857143	1	0.833333	0	1	1
FA_{15}	0.428571	0	0.833333	1	1	0.142857

Table 2: C_i^1, C_i^2, C_i^3 scores.

	C_i^1	C_i^2	C_i^3
FA_1	0.140628	9.553192	0.758056
FA_2	0.123203	6.931164	0.664127
FA_3	0.185511	14.66667	1
FA_4	0.135525	8.400669	0.730548
FA_5	0.038312	3.333333	0.206522
FA_6	0.161898	11.15848	0.872715
FA_7	0.034279	2	0.184783
FA_8	0.180644	13.65073	0.973764
FA_9	0.05979	3.93451	0.3223
FA_{10}	0.141803	9.913381	0.764392
FA_{11}	0.140296	10.38127	0.756265
FA_{12}	0.1238	7.036298	0.667347
FA_{13}	0.14334	10.65073	0.772677
FA_{14}	0.178822	12.71071	0.963942
FA_{15}	0.164872	11.01708	0.888747

Table 3: C_i score.

	C_i
FA_1	4.490057
FA_2	3.400569
FA_3	6.680107
FA_4	4.029345
FA_5	1.490387
FA_6	5.22824
FA_7	0.972804
FA_8	6.27414
FA_9	1.862113
FA_{10}	4.63078
FA_{11}	4.792013
FA_{12}	3.443737
FA_{13}	4.912193
FA_{14}	5.916639
FA_{15}	5.196656

We compare the SVNS-COCOSO with other MCDM methods like TOPSIS, and VIKOR to show the robustness of the suggested methodology. First, we used the dataset and apply it to the TOPSIS and VIKOR approaches to show the rank of the substitutes. Figure 4 shows the order of substitutes by the SVNSs-COCOSo, TOPSIS, and VIKOR. The COCOSO, TOPSIS, and VIKOR have the same best and worst alternatives. So, the proposed methodology is a robust model compared with VIKOR and TOPSIS methods.

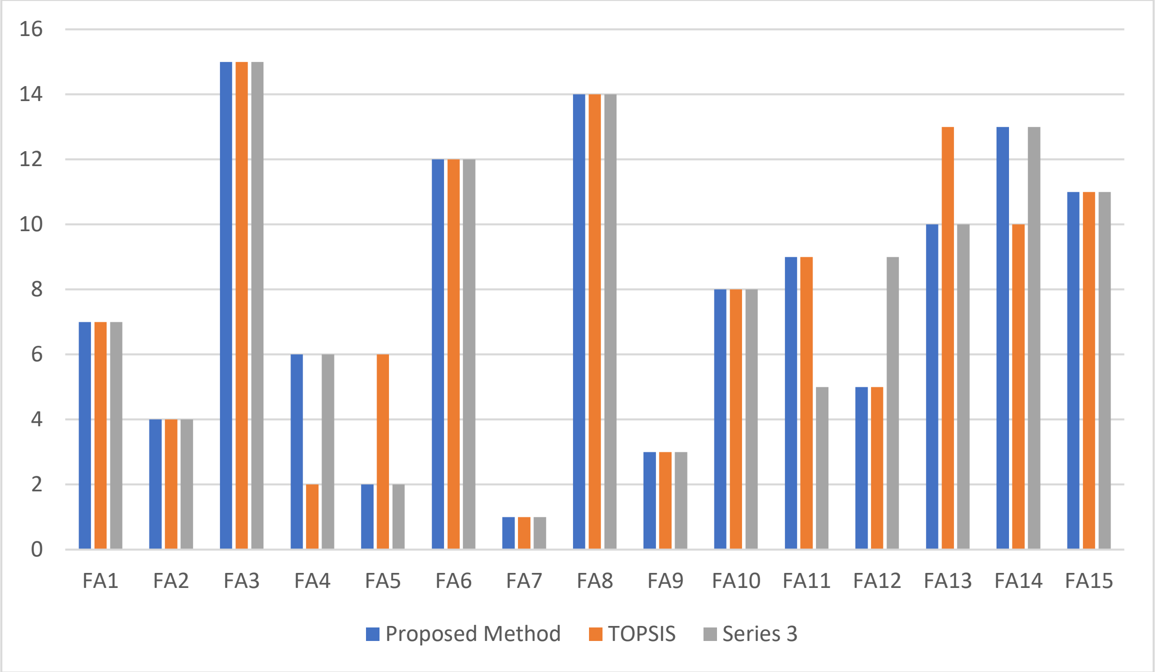

Figure 4: The rank of alternatives by the proposed method, VIKOR, TOPSIS method.

4. Conclusion

It is essential to provide a guarantee for the management of assets in terms of the expected rate of return on investments throughout their anticipated life cycle. Therefore, risk perception for assets and new investments may be implemented during the planning and design phases, and this may be linked with a management strategy that is structured following a risk category. In particular, natural disasters pose a significant danger to both the integrity of the infrastructure and even the lives of people. As a result, the estimation of flood threats in vulnerable zones around the country is unavoidable. The purpose of this research is to develop an MCDM model for identifying more suitable flood risks. An integrated technique has been established in this respect by merging the CoCoSo methodology within the setting of SVNS. To help prioritize the available choices, the CoCoSo methodology has been provided. A case study that included several qualitative and quantitative criteria was provided while taking place within the context of SVNSs. This was done to validate the usefulness of the current technique as well as its practicability. The acquired findings provide evidence that the current strategy is capable of effectively addressing the flood risks assessment issue despite the presence of information that is inconsistent and uncertain. A comparison with earlier models has been considered as a means of confirming the potential of the findings that have been gained.

References

[1] R. B. Mudashiru, N. Sabtu, I. Abustan, and W. Balogun, "Flood hazard mapping methods: A review," *Journal of Hydrology*, vol. 603, p. 126846, 2021.

[2] S. M. H. Shah, Z. Mustaffa, F. Y. Teo, M. A. H. Imam, K. W. Yusof, and E. H. H. Al-Qadami, "A review of the flood hazard and risk management in the South Asian Region, particularly Pakistan," *Scientific African*, vol. 10, p. e00651, 2020.

[3] N. A. Bazai *et al.*, "Increasing glacial lake outburst flood hazard in response to surge glaciers in the Karakoram," *Earth-Science Reviews*, vol. 212, p. 103432, 2021.

[4] P. D. Bates *et al.*, "Combined modeling of US fluvial, pluvial, and coastal flood hazard under current and future climates," *Water Resources Research*, vol. 57, no. 2, p. e2020WR028673, 2021.

[5] M. S. G. Adnan, A. Y. M. Abdullah, A. Dewan, and J. W. Hall, "The effects of changing land use and flood hazard on poverty in coastal Bangladesh," *Land Use Policy*, vol. 99, p. 104868, 2020.

[6] S. Janizadeh *et al.*, "Mapping the spatial and temporal variability of flood hazard affected by climate and land-use changes in the future," *Journal of Environmental Management*, vol. 298, p. 113551, 2021.

[7] K. Khosravi *et al.*, "Convolutional neural network approach for spatial prediction of flood hazard at

national scale of Iran," *Journal of Hydrology*, vol. 591, p. 125552, 2020.

[8] K. Uddin and M. A. Matin, "Potential flood hazard zonation and flood shelter suitability mapping for disaster risk mitigation in Bangladesh using geospatial technology," *Progress in disaster science*, vol. 11, p. 100185, 2021.

[9] D. Ahmad and M. Afzal, "Flood hazards and factors influencing household flood perception and mitigation strategies in Pakistan," *Environmental Science and Pollution Research*, vol. 27, no. 13, pp. 15375–15387, 2020.

[10] H. Zhu and F. Liu, "A group-decision-making framework for evaluating urban flood resilience: a case study in yangtze river," *Sustainability*, vol. 13, no. 2, p. 665, 2021.

[11] H. Akay, "Flood hazards susceptibility mapping using statistical, fuzzy logic, and MCDM methods," *Soft Computing*, vol. 25, no. 14, pp. 9325–9346, 2021.

[12] A. Tella and A.-L. Balogun, "Ensemble fuzzy MCDM for spatial assessment of flood susceptibility in Ibadan, Nigeria," *Natural Hazards*, vol. 104, no. 3, pp. 2277–2306, 2020.

[13] J. S. Chai *et al.*, "New similarity measures for single-valued neutrosophic sets with applications in pattern recognition and medical diagnosis problems," *Complex & Intelligent Systems*, vol. 7, no. 2, pp. 703–723, 2021.

[14] A. R. Mishra, P. Rani, and R. S. Prajapati, "Multi-criteria weighted aggregated sum product assessment method for sustainable biomass crop selection problem using single-valued neutrosophic sets," *Applied Soft Computing*, vol. 113, p. 108038, 2021.

[15] S. Pramanik, "Single-Valued Neutrosophic Set: An Overview," *Transdisciplinarity*, pp. 563–608, 2022.

[16] V. Başhan, H. Demirel, and M. Gul, "An FMEA-based TOPSIS approach under single valued neutrosophic sets for maritime risk evaluation: the case of ship navigation safety," *Soft Computing*, vol. 24, no. 24, pp. 18749–18764, 2020.

[17] S. Ashraf, S. Abdullah, F. Smarandache, and N. ul Amin, "Logarithmic hybrid aggregation operators based on single valued neutrosophic sets and their applications in decision support systems," *Symmetry*, vol. 11, no. 3, p. 364, 2019.

[18] D. Karabašević *et al.*, "A novel extension of the TOPSIS method adapted for the use of single-valued neutrosophic sets and hamming distance for e-commerce development strategies selection," *Symmetry*, vol. 12, no. 8, p. 1263, 2020.

[19] M. Şahin and A. Kargın, "New similarity measure between single-valued neutrosophic sets and decision-making applications in professional proficiencies," in *Neutrosophic Sets in Decision Analysis and Operations Research*, IGI Global, 2020, pp. 129–149.

[20] Z. Turskis, R. Bausys, F. Smarandache, G. Kazakeviciute-Januskeviciene, and E. K. Zavadskas, "M-generalised q-neutrosophic extension of CoCoSo method.," *International Journal of Computers, Communications & Control*, vol. 17, no. 1, 2022.

[21] X. Peng and F. Smarandache, "A decision-making framework for China's rare earth industry security evaluation by neutrosophic soft CoCoSo method," *Journal of Intelligent & Fuzzy Systems*, vol. 39, no. 5, pp. 7571–7585, 2020.

[22] A. Petrovas, R. Baušys, E. K. Zavadskas, and F. Smarandache, "Generation of creative game scene patterns by the neutrosophic genetic CoCoSo method," *Studies in informatics and control*, vol. 31, no. 4, pp. 5–11, 2022.

[23] P. Rani and A. R. Mishra, "Novel single-valued neutrosophic combined compromise solution approach for sustainable waste electrical and electronics equipment recycling partner selection," *IEEE Transactions on Engineering Management*, 2020.

[24] P. Rani, J. Ali, R. Krishankumar, A. R. Mishra, F. Cavallaro, and K. S. Ravichandran, "An integrated single-valued neutrosophic combined compromise solution methodology for renewable energy resource selection problem," *Energies*, vol. 14, no. 15, p. 4594, 2021.

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Appendix

Table 1. The decision matrix.

	FC$_1$	**FC$_2$**	**FC$_3$**	**FC$_4$**	**FC$_5$**	**FC$_6$**
FA$_1$	(0.90, 0.10, 0.10)	(0.30, 0.65, 0.60)	(0.80, 0.30, 0.20)	(0.20, 0.90, 0.80)	(0.90, 0.10, 0.10)	(0.80, 0.30, 0.20)
FA$_2$	(0.80, 0.30, 0.20)	(0.30, 0.65, 0.60)	(0.60, 0.40, 0.30)	(0.80, 0.30, 0.20)	(0.20, 0.90, 0.80)	(0.30, 0.65, 0.60)
FA$_3$	(0.20, 0.90, 0.80)	(0.60, 0.40, 0.30)	(0.90, 0.10, 0.10)	(0.90, 0.10, 0.10)	(0.90, 0.10, 0.10)	(0.90, 0.10, 0.10)
FA$_4$	(0.80, 0.30, 0.20)	(0.60, 0.40, 0.30)	(0.60, 0.40, 0.30)	(0.30, 0.65, 0.60)	(0.20, 0.90, 0.80)	(0.80, 0.30, 0.20)
FA$_5$	(0.20, 0.90, 0.80)	(0.30, 0.65, 0.60)	(0.30, 0.65, 0.60)	(0.90, 0.10, 0.10)	(0.20, 0.90, 0.80)	(0.20, 0.90, 0.80)
FA$_6$	(0.30, 0.65, 0.60)	(0.60, 0.40, 0.30)	(0.30, 0.65, 0.60)	(0.80, 0.30, 0.20)	(0.80, 0.30, 0.20)	(0.30, 0.65, 0.60)
FA$_7$	(0.20, 0.90, 0.80)	(0.30, 0.65, 0.60)	(0.90, 0.10, 0.10)	(0.20, 0.90, 0.80)	(0.20, 0.90, 0.80)	(0.20, 0.90, 0.80)
FA$_8$	(0.90, 0.10, 0.10)	(0.60, 0.40, 0.30)	(0.30, 0.65, 0.60)	(0.90, 0.10, 0.10)	(0.80, 0.30, 0.20)	(0.80, 0.30, 0.20)
FA$_9$	(0.20, 0.90, 0.80)	(0.30, 0.65, 0.60)	(0.30, 0.65, 0.60)	(0.80, 0.30, 0.20)	(0.20, 0.90, 0.80)	(0.30, 0.65, 0.60)
FA$_{10}$	(0.90, 0.10, 0.10)	(0.60, 0.40, 0.30)	(0.90, 0.10, 0.10)	(0.20, 0.90, 0.80)	(0.80, 0.30, 0.20)	(0.20, 0.90, 0.80)
FA$_{11}$	(0.30, 0.65, 0.60)	(0.30, 0.65, 0.60)	(0.30, 0.65, 0.60)	(0.90, 0.10, 0.10)	(0.90, 0.10, 0.10)	(0.80, 0.30, 0.20)
FA$_{12}$	(0.90, 0.10, 0.10)	(0.30, 0.65, 0.60)	(0.60, 0.40, 0.30)	(0.80, 0.30, 0.20)	(0.20, 0.90, 0.80)	(0.30, 0.65, 0.60)
FA$_{13}$	(0.90, 0.10, 0.10)	(0.30, 0.65, 0.60)	(0.30, 0.65, 0.60)	(0.90, 0.10, 0.10)	(0.80, 0.30, 0.20)	(0.80, 0.30, 0.20)
FA$_{14}$	(0.80, 0.30, 0.20)	(0.60, 0.40, 0.30)	(0.80, 0.30, 0.20)	(0.20, 0.90, 0.80)	(0.90, 0.10, 0.10)	(0.90, 0.10, 0.10)
FA$_{15}$	(0.50, 0.50, 0.50)	(0.30, 0.65, 0.60)	(0.80, 0.30, 0.20)	(0.90, 0.10, 0.10)	(0.90, 0.10, 0.10)	(0.30, 0.65, 0.60)

Table 2. The weighted sum matrix.

	FC$_1$	**FC$_2$**	**FC$_3$**	**FC$_4$**	**FC$_5$**	**FC$_6$**
FA$_1$	0.064516	0	0.080645	0	0.258065	0.138249
FA$_2$	0.0553	0	0.048387	0.193548	0	0.023041
FA$_3$	0	0.193548	0.096774	0.225806	0.258065	0.16129
FA$_4$	0.0553	0.193548	0.048387	0	0	0.138249
FA$_5$	0	0	0	0.225806	0	0
FA$_6$	0.009217	0.193548	0	0.193548	0.221198	0.023041
FA$_7$	0	0	0.096774	0	0	0
FA$_8$	0.064516	0.193548	0	0.225806	0.221198	0.138249
FA$_9$	0	0	0	0.193548	0	0.023041
FA$_{10}$	0.064516	0.193548	0.096774	0	0.221198	0
FA$_{11}$	0.009217	0	0	0.225806	0.258065	0.138249
FA$_{12}$	0.064516	0	0.048387	0.193548	0	0.023041
FA$_{13}$	0.064516	0	0	0.225806	0.221198	0.138249
FA$_{14}$	0.0553	0.193548	0.080645	0	0.258065	0.16129
FA$_{15}$	0.02765	0	0.080645	0.225806	0.258065	0.023041

Table 3. The weighted product matrix.

	FC$_1$	**FC$_2$**	**FC$_3$**	**FC$_4$**	**FC$_5$**	**FC$_6$**
FA$_1$	1	0	0.982511	0	1	0.975444
FA$_2$	0.990104	0	0.935122	0.965791	0	0.730624
FA$_3$	0	1	1	1	1	1
FA$_4$	0.990104	1	0.935122	0	0	0.975444

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FA$_{5}$	0	0	0	1	0	0
FA$_{6}$	0.882018	1	0	0.965791	0.961	0.730624
FA$_{7}$	0	0	1	0	0	0
FA$_{8}$	1	1	0	1	0.961	0.975444
FA$_{9}$	0	0	0	0.965791	0	0.730624
FA$_{10}$	1	1	1	0	0.961	0
FA$_{11}$	0.882018	0	0	1	1	0.975444
FA$_{12}$	1	0	0.935122	0.965791	0	0.730624
FA$_{13}$	1	0	0	1	0.961	0.975444
FA$_{14}$	0.990104	1	0.982511	0	1	1
FA$_{15}$	0.946803	0	0.982511	1	1	0.730624