An integrated Neutrosophic sets with MCDM methodology for location-allocation of relief centers

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Abstract

To aid those who have been affected by an earthquake, it is necessary to set up temporary relief facilities. The careful selection of suitable locations for these centers has a considerable impact on the procedures involved in the handling of urban emergencies. In this study, the decision model known as the VIKOR was used to determine the placement of relief centers in Cairo's district and the distribution of available space among them. The selection best location contains uncertainty, so the interval-valued neutrosophic sets were used to overwhelmed this vagueness. To begin, we will use VIKOR, which is the suggested clustering approach. The average method is used to compute the weights of selected criteria. Then the VIKOR technique is used to order and select the best location. The results of the implementation demonstrate that VIKOR, the clustering approach, is adequate in most situations. This strategy is suited for resolving such difficult site selection and allocation issues.

Keywords: Neutrosophic Sets; MCDM; location Allocation; Relief Centers.

1. Introduction

A process known as disaster management can either stop a disaster from happening in the first place or if one does take place, work to mitigate its effects, organize the necessary resources, respond to the emergency, offer immediate assistance, and improve conditions while waiting for normalcy and reconstruction to be completed. Pre-disaster planning has been one of the most pressing concerns for planners and executives in recent years, particularly in the realm of catastrophe management[1], [2].

In most cases, a safe escape operation needs to be carried out either after an earthquake or when the threat of an earthquake is felt[3]. This is necessary to create a secure environment for people who live there get them out of hazardous conditions and prevent unnecessary dangers of aftershocks or supplementary dangers such as fire. A risk-free evacuation may take place voluntarily or in response to a request made by the appropriate authorities[4]–[6]. In the case that the authorities conclude, for any of the reasons, that a secure evacuation is required, they will then issue an order for an emergency evacuation. The term "safe evacuation centers" refers to all safe escape places and spaces where genuine refugees are housed for safe evacuation if it is necessary. These centers also provide the fundamental amenities necessary to fulfil the wants and supplies of asylum seekers for a period of three days[7], [8].

In this research, based on the standard criteria and MCDM, the versatility and effectiveness of the relief centers that were measured by the Egypt Disaster Management in terms of accommodating the injured and patients in disaster and epidemic situations will be evaluated. This study employed neutrosophic sets and the MCDM VIKOR method to select the best location.

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Neutrosophic sets are recognized as the generic framework for the integration of a variety of sets already in existence, like fuzzy sets (FS), intuitionistic fuzzy theory, paraconsistent sets, and so on. These sets were proposed by Smarandache. The primary function of neutrosophic sets (NS) is to describe every logical declaration and set inside a three-dimensional neutrosophic space[9], [10]. In this space, each dimension symbolizes, in turn, the truth (T), the falsity (F), and the indeterminacy (I) of the declaration that is being considered. It is feasible to argue that in the particular instance of a neutrosophic set, it can ascertain not only the truth of data but also its indeterminacy/neutrality and falsity extent, which may be described as new individual parts of FS[11], [12]. This is in comparison to the notions of intuitionistic FS presented by Atanassov, fuzzy sets presented by Zadeh, or other kinds of ambiguity. NS and systems have recently been fast evolving, and they have been demonstrating their relevance in a variety of scientific and technological sectors in recent times. The utilization of NS in the process of decision-making may lead to improved outcomes on account of the indeterminacy parameter's ability to assist in the formulation of membership functions in more depth[12], [13]. On the other hand, based on the description of the NS, we can state that it will be extremely helpful in differentiating between absolute values and relative values. NS can also be used for determining the distinctions between absolute truth and comparative truth, absolute falsity and relative falsehood in logic, absolute membership and non-membership, and relative membership and non-membership[14], [15]. As a consequence of this, many subfields within the scientific and engineering communities have shifted their focus to investigate research topics that are fundamental to NS and logic, neutrosophic odds and statistics, N dynamical systems, and modeling. For example, Smarandache proposed N precalculus and N calculus based on the earlier findings of interval analysis, and evik et al. examined numerous results on the algebras of NS. Both of these examples are examples of N calculus[16]–[18]. In addition, certain other areas that are connected to N, such as N measurement, N probability, and statistics, have not yet been investigated. NS and systems in particular have a considerable deal of application in a variety of subfields of engineering[19]–[22].

The VIKOR approach was first developed by Serafim Opricovic as the first solution to the challenge of making decisions based on several criteria[23], [24]. When it comes to finding solutions to issues involving decision-making, the VIKOR technique employs the idea of a compromise solution. Chang and Hsu employed VIKOR to determine which measures of restraint were the most effective within the Tseng-Wen watershed. Chen and Wang utilized VIKOR in conjunction with the idea of fuzzy logic to choose partners for information systems outsourcing projects[25]. Sayadi and colleagues came up with the VIKOR method to solve problems involving interval-valued decision-making. The VIKOR technique was utilized by Chatterje et al. for the selection of materials, and it was utilized by Civic and Vucijak for the selection of alternative insulation for use in buildings to improve energy efficiency. Sanayei et al. and Shemshadi et al. came up with two distinct linguistically based fuzzy VIKOR procedures to choose a provider. Devi used the fuzzy VIKOR algorithm to the issue of selecting the appropriate robot to be employed in warehouse management[26], [27].

2. Methodology and Problem Description

2.1 Interval-Valued Neutrosophic Sets

Both FS and intuitionistic FS are unable of dealing effectively with a scenario in which the decision may be either acceptable or unacceptable and the assertion of the person making the decision may be uncertain. As a result, we are going to need some brand-new theories to solve the issue of uncertainty. When allocating with indeterminate, imperfect, and unpredictable information, NSs, which consider the truth membership, indeterminacy membership, and falsity membership concurrently, are more practical and acceptable than FSs and intuitionistic FSs. An extension of NSs, which were initially presented by Wang et al., single-valued NS are a type of NS. Ye is credited with the introduction of simplified NS, while Peng et al. are credited with defining their novel processes and agglomeration technicians. NSs may be extended in several ways, such as interval NS, bipolar NS, and multi-valued NS, for example.

Definition 1

A neutrosophic set (NS) Y, which is commonly denoted by Y, may be expressed in the following form if it is specified in the universe of discourse.

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$$B = \langle (y, T_B(y), I_B(y), F_B(y)) : y \in Y \rangle \quad (1)$$

$$0 \leq T_B(y), I_B(y), F_B(y) \leq 3 \quad (2)$$

Definition 2

According to Definition 1, we can see that three factors of a NS are independent and that their total may be up to. This demonstrates how important it is for the neutrosophic parts to be independent of one another.

Definition 3

Let's assume that there is a universal space containing points and that $y \in Y \subset R$. Three different values may be used to describe an interval NS B in Y, and they are the truth membership function, the indeterminacy membership function, and the falsity membership function. In specifically, for each $y \in Y, T_B(y), I_B(y), F_B(y)$, we might display the collection in the following:

$$B = \langle (y, [T_B^L(y), T_B^U(y)], [I_B^L(y), I_B^U(y)], [F_B^L(y), F_B^U(y)]) : y \in Y \rangle \quad (3)$$

$$0 \leq T_B^U(y), I_B^U(y), F_B^U(y) \leq 3 \quad (4)$$

Example 1

Consider an example of a triangular neutrosophic interval number.

The three characterized membership roles of the neutrosophic triangular number interval are shown here.

$$T_B^L(y) = \begin{cases} \frac{y}{4} - \frac{7}{2} & y \in [14,16] \\ 0.5 & y = 16 \\ \frac{11}{6} - \frac{y}{12} & y \in [16,22] \\ 0 & otherwise \end{cases} \quad (5)$$

$$T_B^U(y) = \begin{cases} \frac{y}{5} - \frac{29}{10} & y \in [14,5,16] \\ \frac{3}{10} & y = 16 \\ \frac{129}{110} - \frac{3y}{55} & y \in [16,21.5] \\ 0 & otherwise \end{cases} \quad (6)$$

$$I_B^L(y) = \begin{cases} \frac{-y}{10} - \frac{11}{5} & y \in [12,15] \\ \frac{7}{10} & y = 15 \\ \frac{3y}{20} - \frac{31}{20} & y \in [15,17] \\ 1 & otherwise \end{cases} \quad (7)$$

$$I_B^U(y) = \begin{cases} \frac{-y}{25} + \frac{3}{2} & y \in [12,5,15] \\ \frac{9}{10} & y = 15 \\ \frac{y}{15} - \frac{1}{10} & y \in [15,16.15] \\ 1 & otherwise \end{cases} \quad (8)$$

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$$F_B^L(y) = \begin{cases} \frac{-y}{6} + \frac{7}{2} & y \in [15,18] \\ \frac{1}{2} & y = 18 \\ \frac{y}{6} - \frac{5}{2} & y \in [18,21] \\ 1 & otherwise \end{cases} \tag{9}$$

$$F_B^U(y) = \begin{cases} \frac{-y}{10} + \frac{13}{5} & y \in [16,18] \\ \frac{4}{5} & y = 18 \\ \frac{y}{10} - 1 & y \in [18,20] \\ 1 & otherwise \end{cases} \tag{10}$$

Definition 4

Let O,P be two interval-valued neutrosophic numbers, then their sum is :

$$Sum = \begin{pmatrix} [O_-^L(y) \; + P_-^L(y), O_+^L(y) + P_+^L(y) \;], \\ [O_-^U(y) + P_-^U(y), O_+^U(y) + P_+^U(y) \;], \\ [T\_O_-^L(x) \; + P_-^L(x), O_+^L(x) + P_+^L(x) \;], \\ [O_-^U(x) + P_-^U(x), O_+^U(x) + P_+^U(x) \;], \\ [T\_O_-^L(z) \; + P_-^L(z), O_+^L(z) + P_+^L(z) \;], \\ [O_-^U(z) + P_-^U(z), O_+^U(z) + P_+^U(z) \;] \end{pmatrix} \tag{11}$$

The operation scalar multiplication can be defined as if $\gamma \in \mathbb{R}^-$

$$\gamma B = \begin{pmatrix} [\gamma O_+^L(y) \, , O_-^L(y)]; \\ [\gamma O_+^U(y) \, , O_-^U(y)], \\ [\gamma O_+^L(x) \, , O_-^L(x)]; \\ [\gamma O_+^U(x) \, , O_-^U(x)]' \\ [\gamma O_+^L(z) \, , O_-^L(z)]; \\ [\gamma O_+^U(Z) \, , O_-^U(z)] \end{pmatrix} \tag{12}$$

The operation scalar multiplication can be defined as if $\gamma \in \mathbb{R}^+$

$$\gamma B = \begin{pmatrix} [\gamma O_-^L(y) \, , O_+^L(y)]; \\ [\gamma O_-^U(y) \, , O_+^U(y)], \\ [\gamma O_-^L(x) \, , O_+^L(x)]; \\ [\gamma O_-^U(x) \, , O_+^U(x)]' \\ [\gamma O_-^L(z) \, , O_+^L(z)]; \\ [\gamma O_-^U(Z) \, , O_+^U(z)] \end{pmatrix} \tag{13}$$

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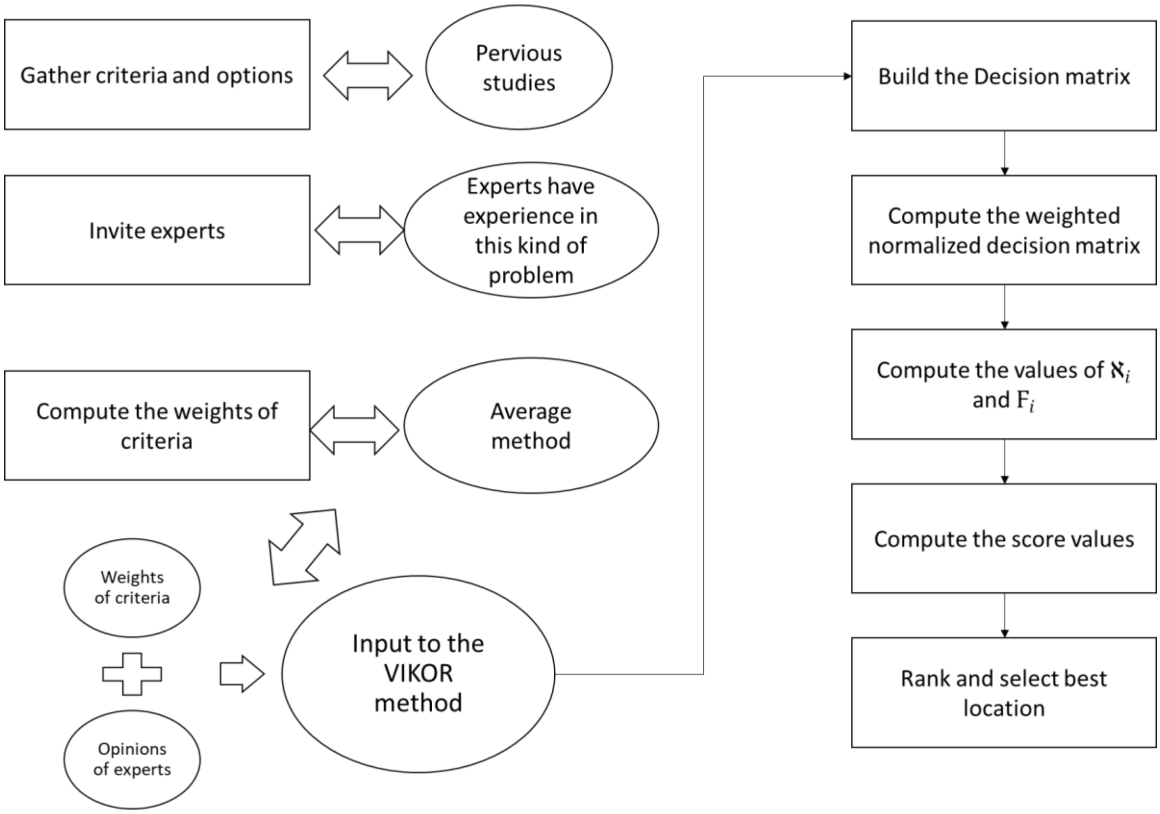

Figure 1: The overview of the research methodology.

2.2 VIKOR MCDM

MCDM, is often used to pick the best viable choice in situations in which the set of possibilities is regulated by a variety of elements known as criteria. On the other hand, the NS is used most often in circumstances that call for taking care of indeterminacy in addition to dealing with uncertainty and certainty. An experts determines the minimum and maximum values for the truth, indeterminacy, and falsity criteria before assigning those values to an interval neutrosophic number. The challenge of mixed INN-MCDM, which refers to the process of selecting the best viable choice given a set of criteria, arises in circumstances like these. The following is a list of the stages that make up the suggested algorithm: figure 1 shows the process in this study.

A choice made by each of the policymakers is considered and the decision matrix is denoted by the letter "D,”. The decision matrix contains an unknown number of options and an unknown number of criteria.

$$D = \begin{pmatrix} \left[\sum_{i=1}^{e} \lambda T_B^L(y), \sum_{i=1}^{e} \lambda T_B^U(y)\right], \\ \left[\sum_{i=1}^{e} \lambda I_B^L(y), \sum_{i=1}^{e} \lambda I_B^U(y)\right], \\ \left[\sum_{i=1}^{e} \lambda F_B^L(y), \sum_{i=1}^{e} \lambda F_B^U(y)\right] \end{pmatrix} \quad (14)$$

Where λ refers to the weight of experts, e refers to the number of experts, I refer to the number of alternatives
An estimation of the various weight considerations

The people in charge of making the choice are being asked to assign relative importance to each criterion that will be used to assess the potential outcomes. The weight of the standards is determined by taking the weights of each criterion and averaging them according to the decision-makers.

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$$R = r_{ij} = \begin{cases} r_{ij}^{L} = \dfrac{t_{ij}^{L}}{\sum_{i=1}^{n} t_{ij}^{U}} \\ r_{ij}^{U} = \dfrac{t_{ij}^{U}}{\sum_{i=1}^{n} t_{ij}^{L}} \end{cases} \quad (15)$$

The computation of a weighted and normalized decision matrix.

To create the weighted normalized decision matrix, we first take the normalized decision matrix (R) that we acquired in the previous step and multiply it by the weight vector w that corresponds to the criterion.

$$WR = r_{ij} w_i \quad (16)$$

Compute the Manhattan distance as

$$\aleph_i = \sum_{j=1}^{n} WR_{ij} \quad (17)$$

Compute the Chebyshev distance as

$$\mathrm{F}_i = \max(WR_{ij}) \quad (18)$$

Compute the value of priority.

$$P_i = 0.5\frac{\aleph_i - \aleph_i^*}{\aleph_i^+ - \aleph_i^*} + 0.5 * \frac{\mathrm{F}_i - \mathrm{F}_i^*}{\mathrm{F}_i^+ - \mathrm{F}_i^*} \quad (19)$$

Where $\aleph_i^*$ is min value, $\aleph_i^+$ max value.

3. Data and Results

When doing the first round of center selection, the VIKOR approach relied on the first six characteristics to make its decisions. The suggested strategy for clustering considered the distance that separated each of the relief centers from one another to exclude the locations that were close to one another.

In the following, a concise explanation will be provided about how each parameter is handled.

Land use

It is believed in this study that open and recreational areas, undeveloped lands, parks, villas and mansions, and car parks are ideal for use as temporary relief centers since these types of locations often have more open space and fewer built portions than other types of locations. To include the land use type in decision modeling, experts provide an appropriateness score for each land use type, with possible values ranging from one to five. The higher the score, the more desirable the land use categories. The ratings of 4, 5, 3, 1, and 2 have been assigned by specialists to the various forms of land use that have been stated.

Area

When it comes to the development of temporary relief facilities in the aftermath of the earthquake, a location's amount of available space is an important consideration.

The distance away from the problem

In light of the destruction that the earthquake produced, relief centers that are located away from any existing fault lines are recommended.

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Population in the vicinity of a location

Establishing relief centers in areas with a higher population density is strongly encouraged. For each site, the blocks inside a one-kilometer buffer of the site were selected. After that, the overall number of these blocks was distributed to the sites, and that population was taken into account when determining the population surrounding each site.

Slope

The bitmap graphics slope map of the region was converted into point features. The slope of each location was determined by looking at the slope of the point that was closest to it.

The slope of each location was determined by looking at the slope of the point that was closest to it.

The amount of space that separates centers from major thoroughfares.

Calculate the distance between centers and the main routes of District 1, and this distance was taken into consideration as one of the choice variables.

Beneficial criteria for this investigation include land use (RC1), region (RC2), range from fault lines (RC3), and density (RC4). Criteria for this investigation that are unfavorable include slope (RC5) and range from routes (RC6).

At this point in the process, we are going to rate all 3065 sites that are currently accessible based on the first six criteria. The VIKOR method is used to compute the weights of criteria by letting decision-makers evaluate the criteria and then compute the weights by the average method as shown in figure 2.

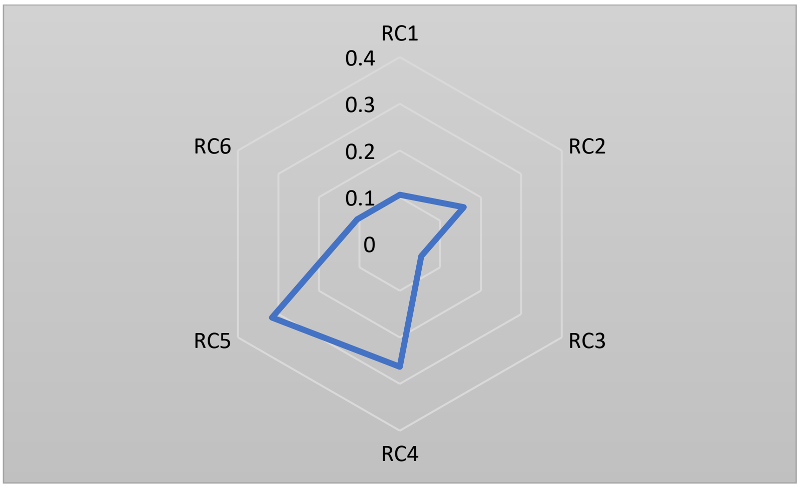

Figure 2: The weights of six parameters.

Let experts rank the standards and alternatives to build the decision matrix. Then substitute the opinions of experts with the neutrosophic numbers as shown in table 1. Then normalize the decision matrix. Then calculate the weighted normalized decision matrix as shown in table 2. They calculate the values of the VIKOR method. Compute the values of $\aleph_i$ and F_i as shown in table 3. Then use the ordering of the VIKOR method to order and select the best site from 10 sites as shown in figure 3. From figure 3 site 4 is the best site followed by site 2 and site 3. Site 7 is the lowest rank.

Table 1: The Decision matrix between criteria and alternatives.

	RC_1	RC_2	RC_3	RC_4	RC_5	RC_6
RA_1	⟨⟨[0.05, 0.2], [0.6, 0.7], [0.75, 0.9]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.05, 0.2], [0.6, 0.7], [0.75, 0.9]⟩	⟨⟨[0.45, 0.6], [0.3, 0.4], [0.35, 0.5]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩

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RA_2	⟨⟨[0.45, 0.6], [0.3, 0.4], [0.35, 0.5]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.55, 0.7], [0.4, 0.5], [0.25, 0.4]⟩	⟨⟨[0.55, 0.7], [0.4, 0.5], [0.25, 0.4]⟩	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩
RA_3	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.4, 0.6], [0.1, 0.2], [0.4, 0.6]⟩	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩	⟨⟨[0.45, 0.6], [0.3, 0.4], [0.35, 0.5]⟩	⟨⟨[0.65, 0.8], [0.5, 0.6], [0.15, 0.3]⟩
RA_4	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩	⟨⟨[0.45, 0.6], [0.3, 0.4], [0.35, 0.5]⟩	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩	⟨⟨[0.45, 0.6], [0.3, 0.4], [0.35, 0.5]⟩	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩
RA_5	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.45, 0.6], [0.3, 0.4], [0.35, 0.5]⟩	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩
RA_6	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩	⟨⟨[0.75, 0.9], [0.6, 0.7], [0.05, 0.2]⟩
RA_7	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩
RA_8	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.15, 0.3], [0.5, 0.6], [0.65, 0.8]⟩	⟨⟨[0.65, 0.8], [0.5, 0.6], [0.15, 0.3]⟩	⟨⟨[0.65, 0.8], [0.5, 0.6], [0.15, 0.3]⟩	⟨⟨[0.45, 0.6], [0.3, 0.4], [0.35, 0.5]⟩
RA_9	⟨⟨[0.55, 0.7], [0.4, 0.5], [0.25, 0.4]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.65, 0.8], [0.5, 0.6], [0.15, 0.3]⟩
RA_{10}	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩	⟨⟨[0.05, 0.2], [0.6, 0.7], [0.75, 0.9]⟩	⟨⟨[0.55, 0.7], [0.4, 0.5], [0.25, 0.4]⟩	⟨⟨[0.25, 0.4], [0.4, 0.5], [0.55, 0.7]⟩	⟨⟨[0.55, 0.7], [0.4, 0.5], [0.25, 0.4]⟩	⟨⟨[0.35, 0.5], [0.3, 0.4], [0.45, 0.6]⟩

Table 2: The weighted normalization decision matrix between criteria and alternatives.

	RC_1	RC_2	RC_3	RC_4	RC_5	RC_6
RA_1	0.105263	0.078947	0.039474	0.263158	0.157895	0
RA_2	0.045113	0.078947	0	0.075188	0	0.105263
RA_3	0.090226	0.019737	0.026316	0	0.157895	0.084211
RA_4	0	0	0.026316	0.112782	0	0.105263
RA_5	0.090226	0.078947	0.039474	0.112782	0.315789	0.021053
RA_6	0	0.118421	0.039474	0	0.210526	0.105263
RA_7	0.06015	0.118421	0.026316	0.225564	0.315789	0.021053
RA_8	0.075188	0.118421	0.052632	0.037594	0.052632	0.042105
RA_9	0.030075	0.078947	0.026316	0.18797	0.263158	0.084211
RA_{10}	0.06015	0.157895	0	0.18797	0.105263	0.021053

Table 3: The values of $\aleph_i$ and F_i.

	$\aleph_i$	F_i
RA_1	0.644737	0.263158
RA_2	0.304511	0.105263
RA_3	0.378383	0.157895
RA_4	0.244361	0.112782
RA_5	0.658271	0.315789
RA_6	0.473684	0.210526
RA_7	0.767293	0.315789
RA_8	0.378571	0.118421
RA_9	0.670677	0.263158
RA_{10}	0.532331	0.263158

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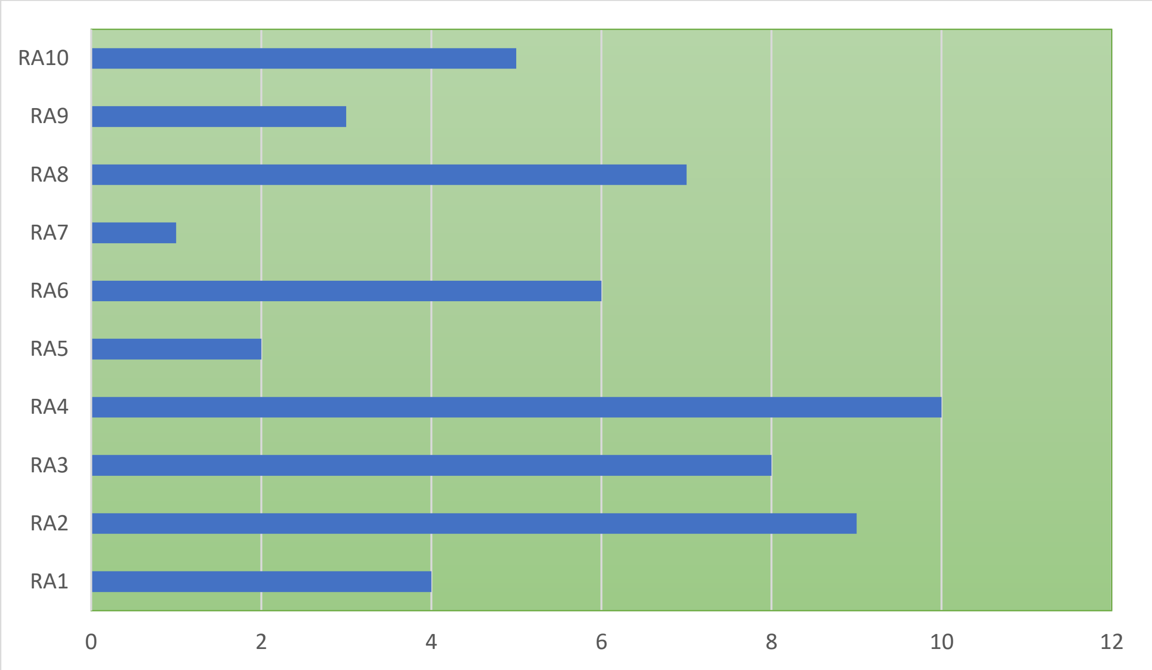

Figure 3: The ordering of 10 sites.

4. Conclusion

Choosing the appropriate locations for temporary relief centers after an earthquake may have an effect not only on the reaction time but also on the effectiveness of the relief operations that are carried out. Regarding this matter, several solutions have been proposed up to this point. In this study, a very simple clustering approach is suggested and utilized alongside VIKOR to initially choose appropriate candidate centers based on their land use, area, distance from the fault lines and primary routes, slope, and population. These factors were taken into consideration to determine the proper candidate centers. Consequently, the outcomes of these two approaches were not taken into consideration.

The objective was to choose a small number of centers, ten in all, from among these locations so that the packets may be distributed between them most effectively.

This study analyses the relationship between the criterion to calculate the weights of the standards using N-VIKOR by the average method. Following that, the N-VIKOR technique is used to assess and rank the sites based on how well they meet the criteria that were set. The research team and the specialists who participated in this study trust that the decision-making ideal that has been developed will enable policymakers to rethink comparable procedures to take choices that are acceptable in practice.

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