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Enhanced Technique for Operation Evaluation of Distribution Network Automation Systems Based on the Uncertainty Environment

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Abstract:

Evaluation of the distribution network automation systems is a complex task due to it containing various criteria. So, this evaluation is an multi-criteria decision making (MCDM) problem. We used the VIKOR method to rank the alternatives. The VIKOR method is integrated with the plithogenic set to deal with uncertainty information in the evaluation distribution network automation system. Three experts are invited to evaluate the criteria and alternatives. An application with eight criteria and 12 alternatives is collected to select the highest importance criterion and highest score alternatives. The results show the System Reliability and Stability criterion has the highest importance and the User Interface and Control Systems criterion has the lowest importance. We performed sensitivity analysis with ten cases to show the different rank of alternatives. The results show the proposed method is stable in different cases.

Keywords: Distribution Network Automation Systems; Multi-Criteria Decision Making; Uncertainty Environment; VIKOR Method.

1. Introduction

One of the most effective strategies to increase the dependability of electrical distribution networks is network automation. It shortens the time that consumers are interrupted and the number of impacted customers. Network automation relies heavily on fault indicators (FPIs) and remotely operated and supervised switches (such as reclosers and sectionalizing switches (RCSs). Distributed generators (DGs) operating on islands can increase distribution networks' dependability even more. An island will be constructed if generation can supply loads without breaching the operational limits during the island operation. Therefore, when designing for network automation, the best island partitioning should be considered. This is made possible by automatic switching devices, such as reclosers and RCSs[1], [2].

The network automation planning challenge becomes even more difficult as a result. Numerous strategies have been put forth that maximize the quantity, kind, and placement of automation devices (ADs) in distribution networks while taking DG island operation into account. They consider reliability indices, the cost to consumers of both short-term and long-term interruptions, the cost of automation devices, and the cost of DGs to determine the optimal network automation strategy and DG placement[3], [4]. Evaluation of the network automation systems is a MCDM problem.

Experts feel at ease using linguistics such as "Very Important," "Important," "Medium," and "Average" to convey the necessary information. Due to their ambiguity, these concepts must be quantified to be used for analysis. To employ these linguistic notions in analysis, Zadeh created the idea of fuzzy sets, in which an element's degree of membership determines how gradually it changes from a member to a non-member[5], [6]. These sets were further expanded to include intuitionistic fuzzy sets (IFS), interval valued intuitionistic fuzzy sets (IVIFS), and interval valued fuzzy sets (IVFS). Research tackling MCDM issues under ambiguity has made extensive use of fuzzy sets[7], [8].

However, none of these sets were able to account for the element's membership indeterminacy component. Any of the fuzzy sets listed above are unable to handle the following scenarios: 0.4 for the statement to be true, 0.3 for the statement to be false, and 0.5 for the statement to be uncertain[9], [10]. To get around the drawbacks of fuzzy sets where indeterminacy is openly described, Smarandache created the neutrosophic set (NS). In a universal set X, where X contains real standard or nonstandard subsets, a neutrophilic set is defined as set A that is separately characterized by a truth membership function, indeterminacy membership function, and falsity membership function[11], [12].

When applied with consideration for the degree of disagreement between each attribute value and the dominating attribute values of the data, the plithogenic set, which was developed as an extension of the neutrosophic set, can handle data uncertainty and produce results that are significantly better than the neutrosophic set. Plithogenic sets were successfully applied by researchers to MCDM issues[13], [14].

In MCDM, a compromise ranking technique called VIKOR is employed. By considering conflicting criteria and offering compromise solutions that maximize collective value and reduce individual regret, it aids in ranking and choosing alternatives. VIKOR, which focuses on identifying the option that is closest to the optimum solution, is especially helpful when decision makers are unable to articulate their preferences[15], [16].

The main purpose of this paper is

(1) To aim to convert the plithogenic number into crisp values.
(2) To establish an MCDM method to compute the criteria weights and rank the distribution network systems.
(3) To develop a VIKOR method to rank the alternatives.
(4) To illustrate with an example and the effectiveness of the proposed method.
(5) To perform the sensitivity analysis.

The rest of this study is organized as follows: Section 2 shows the Preliminaries operations. Section 3 shows the proposed methodology steps. Section 4 shows the illustrative example of this study. Section 5 shows the sensitivity analysis. Section 6 shows the conclusions.

2. Preliminaries

This section shows some definitions of plithogenic sets and their operations.

2.1 Plithogenic Set

As an expansion of the concepts of crisp, fuzzy, intuitionistic fuzzy, and neutrosophic sets, Smarandache introduced the idea of plithogenic sets. One or more qualities may be present in a plithogenic set P, and each attribute may have many values. According to certain specified criteria, the value v of each attribute corresponds to the (fuzzy, intuitionistic fuzzy, or neutrosophic) degree of appurtenance d(x, v) of the element x to the set P. A (fuzzy, intuitionistic fuzzy, or neutrosophic) contradiction (dissimilarity) degree between every characteristic value and the dominant characteristic value is established in order to improve the accuracy of the plithogenic aggregation operations. The most significant characteristic value is determined and given a dominating value by experts. If a dominant attribute value is absent or has many dominant attribute values, experts might choose to suppress it or create another association function.

2.2 Plithogenic Set Theoretic Operations

Plithogenic operations can be defined as:

$$d_{AB}(x, v_T) = \begin{pmatrix} (T, I, F) \\ \big((1 - cd_i)[d_A(x, v_T)]t_{conorm}\ d_B(x, v_T)\big) \\ +cd_i[d_A(x, v_T)]t_{conorm}\ d_B(x, v_T)\ , \\ \frac{1}{2}[d_A(x, v_I)]t_{conorm}\ d_B(x, v_I) + [d_A(x, v_I)]t_{conorm}\ d_B(x, v_I), \\ (1 - cd_i)[d_A(x, v_F)]t_{norm}\ d_B(x, v_F) \\ +cd_i[d_A(x, v_F)]t_{norm}\ d_B(x, v_F) \end{pmatrix} \quad (1)$$

$$d_{AB}(x, v_T) = \begin{pmatrix} (T, I, F) \\ \big((1 - cd_i)[d_A(x, v_T)]\vee_f\ \ d_B(x, v_T)\big) \\ +cd_i[d_A(x, v_T)]\wedge_f\ d_B(x, v_T)\ , \\ \frac{1}{2}[d_A(x, v_I)]\wedge_f\ d_B(x, v_I) + [d_A(x, v_I)]\vee_f\ d_B(x, v_I), \\ (1 - cd_i)[d_A(x, v_F)]\wedge_f\ d_B(x, v_F) \\ +cd_i[d_A(x, v_F)]\vee_f\ d_B(x, v_F) \end{pmatrix} \quad (2)$$

3. The Proposed Model

The proposed model uses plithogenic numbers and VIKOR method to evaluate the criteria and rank the alternatives. Set of experts identify the framework to evaluate the criteria and list of alternatives and these criteria and affect on the decision-making process. They can decide the contradiction degrees of criteria, obtain combined alternatives score using the plithogenic sets and VIKOR method. Figure 1 shows the steps of the proposed methodology. The process is summarized below:

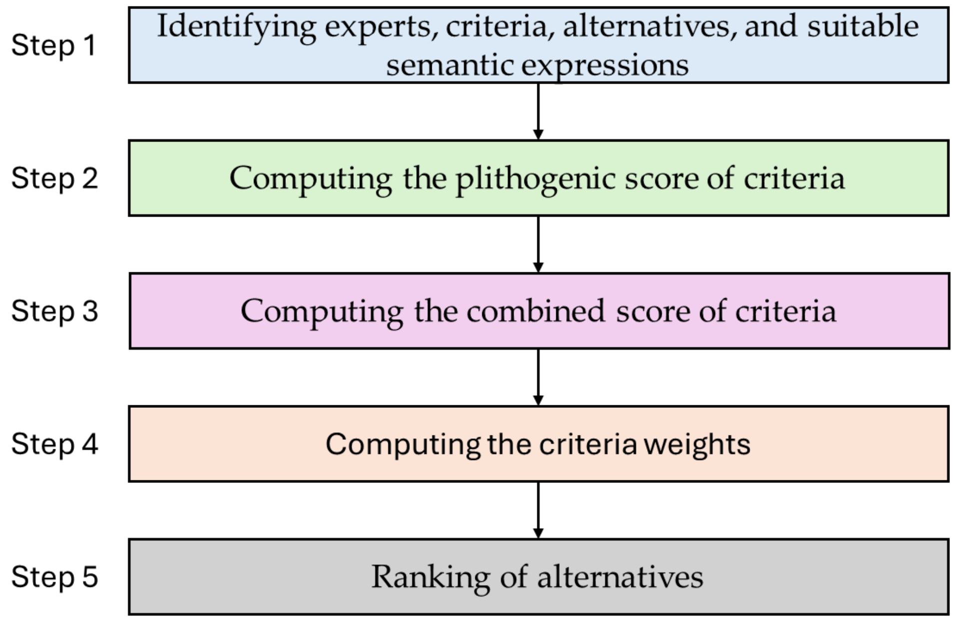

Figure 1. Flowchart of proposed model.

Step 1. Identifying experts, criteria, alternatives, and suitable semantic expressions.

We form a committee of k experts $E = \{E_1, \dots, E_k\}$ to define list n criteria $C = \{C_1, \dots, C_j\}$ and list m alternatives $A = \{A_1, \dots, A_i\}$. If $E_t = (a_t, b_t, c_t)$ is a plithogenic number expressing the importance of experts and crisp value can be obtained as:

$$S(E) = \frac{(2 + a_t - b_t - c_t)}{3} \quad (3)$$

After normalizing these crisp values for experts, we can obtain weights of experts.

Step 2. Computing the plithogenic score of criteria

Plithogenic score of criteria can be computed by the product of plithogenic descriptions. The plithogenic score can be computed using the plithogenic operator.

Step 3. Computing the combined score of criteria

The criteria score obtained for all decision makers and experts using the plithogenic operations intersection. Then we apply the score function to obtain crisp values in the combined matrix. Then we normalize the matrix to obtain the criteria weights.

Step 4. Ranking of alternatives.

We apply the steps of the VIKOR method under the plithogenic numbers to rank the alternatives.

Compute the maximum and minimum score of each column in the combined decision matrix for beneficial and non-beneficial criteria.

$$\begin{Bmatrix} y_j^* = \max y_{ij} \\ y_j^- = \min y_{ij} \end{Bmatrix} \tag{4}$$

$$\begin{Bmatrix} y_j^* = \min y_{ij} \\ y_j^- = \max y_{ij} \end{Bmatrix} \tag{5}$$

Where $i = 1, \dots, m; j = 1, \dots, n$

The S and R indexes

$$S_i = \sum_{j=1}^{n} w_j \frac{\left(y_j^* - f_{ij}\right)}{\left(y_j^* - y_j^-\right)} \tag{6}$$

$$R_i = \max\left[w_j \frac{\left(y_j^* - f_{ij}\right)}{\left(y_j^* - y_j^-\right)}\right] \tag{7}$$

The VIKOR index

$$U_i = v \times \left[\frac{(S_i - \max S_i)}{(\min S_i - \max S_i)}\right] + (1 - v \times)\left[\frac{(R_i - \max R_i)}{(\min R_i - \max R_i)}\right] \tag{8}$$

The final ranking of alternatives

The alternatives are ranked by the lowest value in VIKOR index

4. Illustrative Example

Consider an organization system and need to select the optimal Operation Evaluation of Distribution Network Automation Systems. Here are three experts from the network automation system who are invited through semi structured interviews to identify and list the various criteria and alternatives.

Step 1. In this step we collect seven criteria and 12 systems to be evaluated and select the highest score system to be applied in the operations firm. Figure 2 shows the list of criteria that are used in this study.

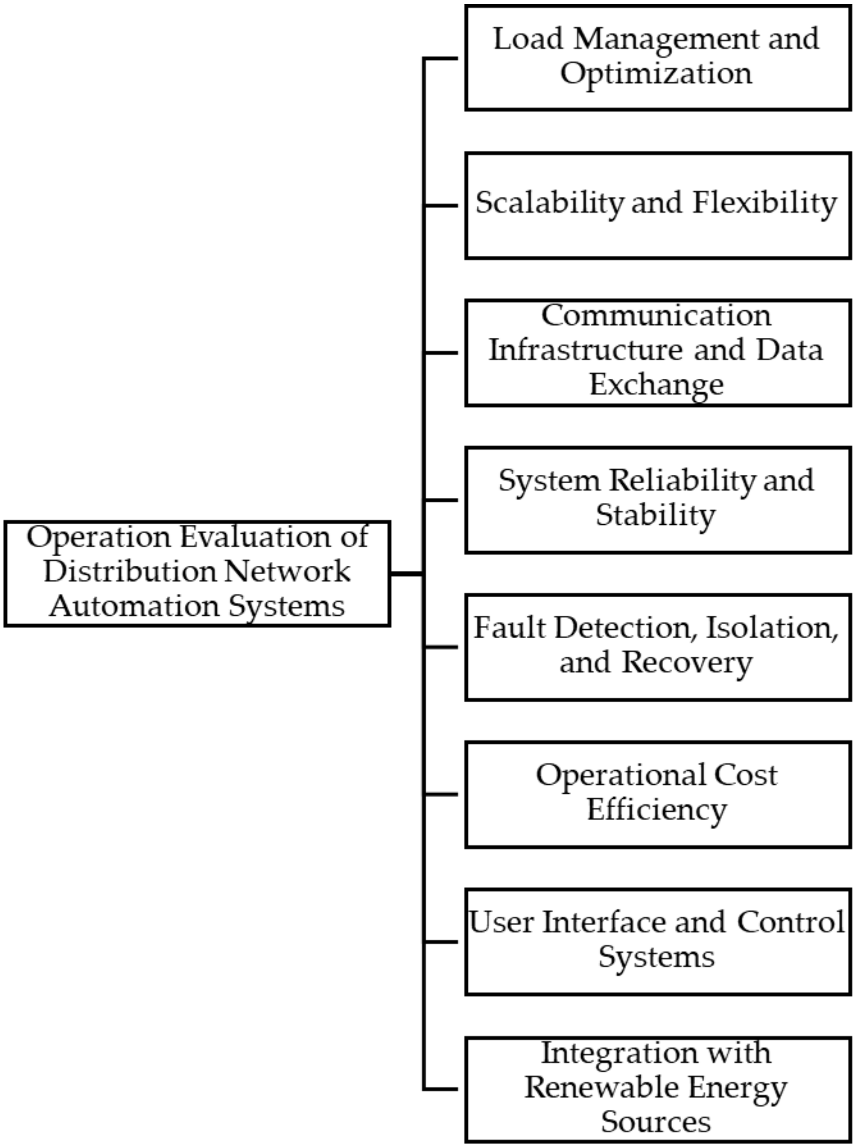

Figure 2. The operations of distributions network automation system criteria.

Step 2. This step lets three experts and decision makers evaluate the criteria. Then we replaced their opinions by using the plithogenic numbers as shown in Tables 1-3.

Table 1. The plithogenic numbers by expert 1

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)
A_2	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
A_3	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)
A_4	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
A_5	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)
A_6	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)
A_7	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)
A_8	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)
A_9	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)

A_{10}	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.80, 0.10, 0.30)	(0.40, 0.70, 0.50)
A_{11}	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)
A_{12}	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)

Table 2. The plithogenic numbers by expert 2

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)
A_2	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_3	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
A_4	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)
A_5	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)
A_6	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)
A_7	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)
A_8	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)
A_9	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)
A_{10}	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)
A_{11}	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)
A_{12}	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)

Table 3. The plithogenic numbers by expert 3

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)
A_2	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_3	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)
A_4	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)
A_5	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)
A_6	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)
A_7	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)
A_8	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
A_9	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_{10}	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)
A_{11}	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)
A_{12}	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)

Step 3. This step combines the different opinions of experts by using the plithogenic operator. Then we obtain crisp values. Then we normalize these values to obtain the criteria weights. Then we rank the criteria as:

$$C4 > C5 > C1 > C8 > C3 > C2 > C6 > C7$$

We show criterion 4 has the highest importance and criterion 7 has the lowest importance.

Step 4. This step applies the steps of the VIKOR methodology to rank the alternatives.

Then we obtain the normalized decision matrix shown in Table 4. Then we obtain the matrix of weighted normalized as in Table 5. Then we obtained the values of the S and R index.

Table 4. The normalized matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.309892	1	0.534896	0.714349	0.400332	0	0	0.524087
A_2	0.553889	0.632791	0.145436	0.171169	0	1	0.772905	1

A_3	0.449574	0.645141	0.455726	0.300376	0.877332	0.073825	0.520457	0.7211
A_4	0.380254	0.68643	0.200871	0.044951	0.452466	0.823258	0.340121	0.508677
A_5	0.129519	0.167356	0.056307	0.022254	0.950549	0.331694	0.072447	0.136463
A_6	0.147277	0.095609	0.400622	1	0.252747	0.618731	0.180559	0
A_7	0.153308	0.167356	0	0.602192	0.652568	0.418047	0.40959	0.005216
A_8	0.492759	0.377937	1	0.26384	0.877332	0.242266	0.380254	0.793789
A_9	0.407282	0.284159	0.049585	0	0.124329	0.154106	0.757232	0.494263
A_{10}	0.329846	0.885237	0.166763	0.562555	0.309865	0.390531	0.378392	0.322617
A_{11}	1	1	1	0.562555	0.877332	0.317513	0.404601	0.651304
A_{12}	0	0	0.145436	0.891275	1	0.431805	1	0.218777

Table 5. The weighted normalized matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.039996	0.120884	0.064683	0.097212	0.053843	0	0	0.063395
A_2	0.071488	0.076494	0.017587	0.023294	0	0.120058	0.090832	0.120963
A_3	0.058025	0.077987	0.05511	0.040877	0.117997	0.008863	0.061165	0.087227
A_4	0.049078	0.082978	0.024291	0.006117	0.060855	0.098839	0.039971	0.061531
A_5	0.016716	0.020231	0.006809	0.003028	0.127845	0.039823	0.008514	0.016507
A_6	0.019008	0.011558	0.048446	0.136085	0.033993	0.074284	0.021219	0
A_7	0.019787	0.020231	0	0.08195	0.087768	0.05019	0.048135	0.000631
A_8	0.063598	0.045686	0.120927	0.035905	0.117997	0.029086	0.044688	0.096019
A_9	0.052566	0.03435	0.005996	0	0.016722	0.018502	0.08899	0.059788
A_{10}	0.042572	0.107011	0.020166	0.076556	0.041675	0.046886	0.044469	0.039025
A_{11}	0.129066	0.120884	0.120927	0.076556	0.117997	0.03812	0.047549	0.078784
A_{12}	0	0	0.017587	0.12129	0.134496	0.051842	0.117521	0.026464

Then we obtained the VIKOR index as in Table 6. We used v=0.5. Then we ranked the alternatives as in Table 6.

Table 6. The rank of alternatives.

	S	*R*	*VIKOR index*	*Rank*
A_1	0.440014	0.120884	0.452847	6
A_2	0.520717	0.120963	0.369741	9
A_3	0.50725	0.117997	0.414165	7
A_4	0.42366	0.098839	0.697641	3
A_5	0.239473	0.127845	0.585276	5
A_6	0.344594	0.136085	0.392823	8
A_7	0.308691	0.087768	0.929428	2
A_8	0.553907	0.120927	0.336278	10

A_9	0.276914	0.08899	0.949172	1
A_{10}	0.41836	0.107011	0.618483	4
A_{11}	0.729882	0.129066	0.07264	12
A_{12}	0.469199	0.134496	0.282233	11

5. Sensitivity Analysis

The sensitivity analysis is performed to see the effectiveness of the proposed models under uncertainty environment. In the VIKOR method, we put the v=0.5 in the VIKOR index. In this section, we change the v value from 0 to 1. Then we rank the alternatives. Figure 3 shows the rank of alternatives under different v values. We show the rank of alternatives is stable under different v values. So, the proposed model is effective.

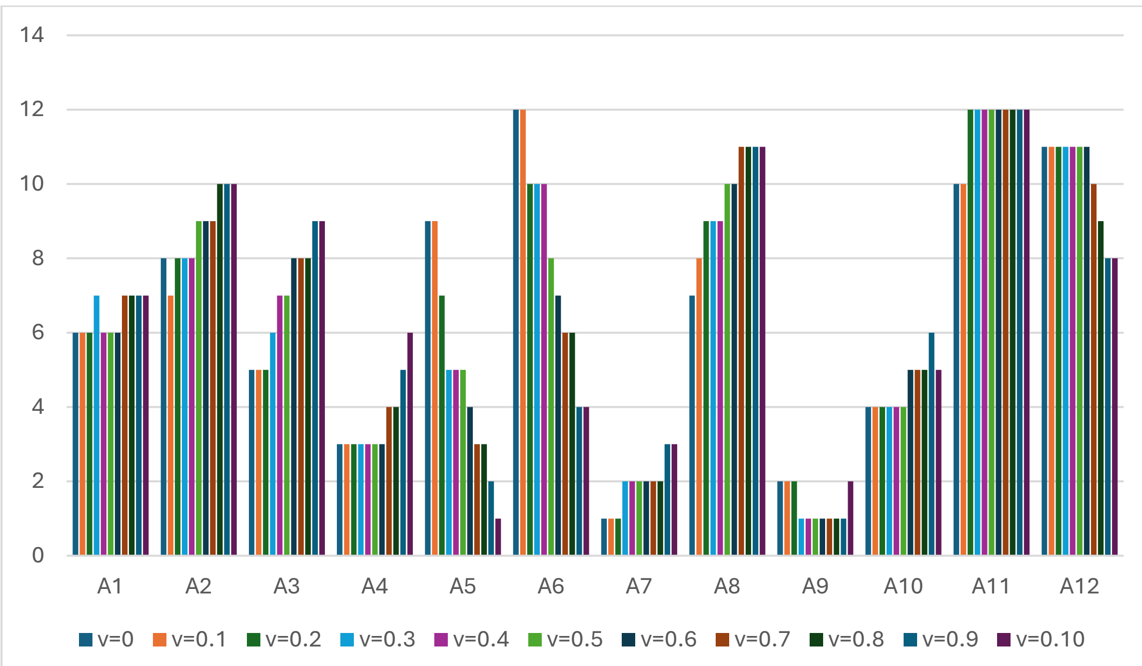

Figure 3. The rank of alternatives under different v values.

6. Conclusions

The goal of this study is to propose an MCDM methodology under the plithogenic sets and VIKOR methodology. We used plithogenic numbers to evaluate the criteria and alternatives. Three experts and decision makers are invited to evaluate the criteria and alternatives to build the decision matrix. We combined these numbers into a single matrix using the plithogenic operator. We obtain crisp values instead of plithogenic numbers. Eight criteria and 12 alternatives are collected in this study. We compute the criteria weights to rank the criteria to show the highest and lowest importance. Then we applied the VIKOR method to rank the alternatives. We show alternative 11 is the best and alternative 9 is the worst.

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