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Plithogenic Sets-Based MABAC Framework for Evaluating the Quality of Elderly Care Security Services for Left-Behind Elderly in Rural Areas of Western China: A Healthcare Industry Perspective

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Abstract:

This study proposed a multi-criteria decision-making (MCDM) methodology for evaluating the elderly care security services. These services consist various criteria, so the MCDM methodology is used. MABAC methodology is a MCDM method used to rank the alternatives. The MABAC methodology is integrated under the plithogenic sets to deal with vague and uncertainty data. The plithogenic sets are an extension of neutrosophic sets to deal with inconsistencies data. The criteria weights are computed in this study. Seven criteria and 13 alternatives are collected in this study. An application with opinions of three experts evaluate the criteria and alternatives. The results show the criterion Accessibility of Services has the highest weights and the criterion Technological Integration in Care Services has the lowest weights. The sensitivity analysis is performed to show the stability of rank of alternatives.

Keywords: Elderly Care Security Services; Plithogenic Sets; Healthcare Industry; MABAC Framework; Left-Behind Elderly in Rural Areas.

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1. Introduction

Elcare is a start-up providing socially conscious healthcare services. Our goal is to offer senior parents top-notch security, convenience, and care services. Elcare, which is run by a group of highly skilled professionals, provides a comprehensive range of services aimed at meeting all the needs of senior citizens and enhancing their general quality of life as well as their mental, physical, and emotional well-being[1], [2].

Elcare works hard to deliver the best senior care possible. Our staff of CareMates and CareAngels is amiable and well-trained, and they are prepared to handle any need that an older person may have. The caregivers at Elcare are the partner your elderly parents need at every stage to make their life better and easier, from attending to their health and wellness needs to help them and making it convenient for them to carry out daily tasks to handling any emergencies or crises[3], [4].

Elcare is only a phone call away if you're searching for a trustworthy and qualified senior care service provider! Elcare employs a team of knowledgeable, kind, and highly qualified people who are committed to helping the elderly with everything from everyday activities and outings to financial, legal, and medical advice. Elcare provides a range of senior care packages designed to meet the different needs of senior citizens and support them in living a stress-free, comfortable, and peaceful life[5], [6].

Making decisions is common in many domains, such as the management, social, and economic sectors. It includes tasks like business location, program selection, quality assessment, project evaluation, investment choice, resource allocation, staff evaluation, scientific research assessment, and overall grading of economic benefits. Scientific decision analysis is essential to modern management, and scientific decision making is the key to management success. An essential component of decision analysis, MCDM helps DMs score many options based on a predetermined set of criteria[7], [8].

DMs often bring in subject-matter experts throughout the assessment process. Expert evaluations are often uncertain since DMs are often evaluated using fuzzy numbers rather than precise ones due to the complicated environment and human preferences[9], [10], [11], [12]. To deal with this, Zadeh developed the idea of fuzzy sets, which are a useful tool for managing imprecise data. Since then, scholarly literature has proposed a number of expanded classifications for fuzzy sets[13], [14]. This research considers plithogenic sets in performance analysis to eliminate ambiguity in MCDM. In short, the plithogenic set is the neutrosophic set generalized[15], [16].

Ranking the options is the next crucial step in the MADM process. An essential instrument in this process is the widely used classical MABAC technique, which was developed by Pamučar & Ćirović. Determining how far each option is from the Border Approximation Area (BAA) is a crucial step. Among the many benefits that MABAC provides are simple computations, lucid reasoning, reliable results, and smooth interoperability with other algorithms. Researchers have used MABAC in a variety of domains because of its advantages[17], [18].

The following are the primary ways in which this study has contributed:

- We introduce an evaluation framework under the plithogenic sets to deal with vague and uncertainty information. This model uses the opinions of experts to evaluate the criteria and alternatives.
- The MABAC method is used as a MCDM method to rank the alternatives based on plithogenic numbers.
- Application with seven criteria and 13 alternatives are considered to validate the proposed methodology.
- A sensitivity analysis is conducted to show the rank of alternatives is stable under different criteria weights.

The rest of this paper is organized as follows: Section 2 shows the plithogenic sets operations. Section 3 shows the steps of the MABAC method under the plithogenic sets. Section 4 shows the application of this study. Section 5 shows the sensitivity analysis. Section 6 shows the conclusions.

2. Plithogenic Sets

Plithogenic set is a generalization of the neutrosophic sets and the attribute values are the component of Plithogenic set. The Plithogenic set (P, A, V, d, c) is a set that has several components defined by number of criteria $A = \{a_1, \dots, a_m\}, m \geq 1$ and their values are $V = \{v_1, \dots, v_n\}, n \geq 1$. Contradiction $[c(v, D)]$ and appurtenance degrees functions $[d(x, v)]$ are the advantages elements of the Plithogenic sets[19].

In this study, the Plithogenic aggregation operation is applied to combine various evaluations of decision-making groups on input and output performance values with respect to all alternatives. This approach includes the following steps.

Step 1. In this study the evaluations of group decision making are used as input and output with review of experts. Their evaluations include the linguistic terms between criteria and alternatives. These terms are converted to the Plithogenic numbers to reflect uncertainty in this study.

Step 2. The dominant criterion between inputs and outputs is computed and the contradiction degrees of each input and output are defined. Then all decision-making evaluations by experts and decision makers are combined with the Plithogenic operator as:

$$\left((a_{i1}, a_{i2}, a_{i3})\wedge_p(b_{i1}, b_{i2}, b_{i3})\right) = \begin{pmatrix} a_{i1}\wedge_F b_{i1}, \\ \frac{1}{2}(a_{i2}\wedge_F b_{i2}) + \frac{1}{2}(a_{i2}\vee_F b_{i2}), \\ (a_{i3}\vee_F b_{i3}) \end{pmatrix}$$

(1)

Step 3. The combined evaluations are Plithogenic numbers are they are converted to crisp values such as:

$$s(A) = \frac{(2+a_1-b_1-c_1)}{3} \quad (2)$$

Step 4. Normalize crisp values to compute the criteria weights.

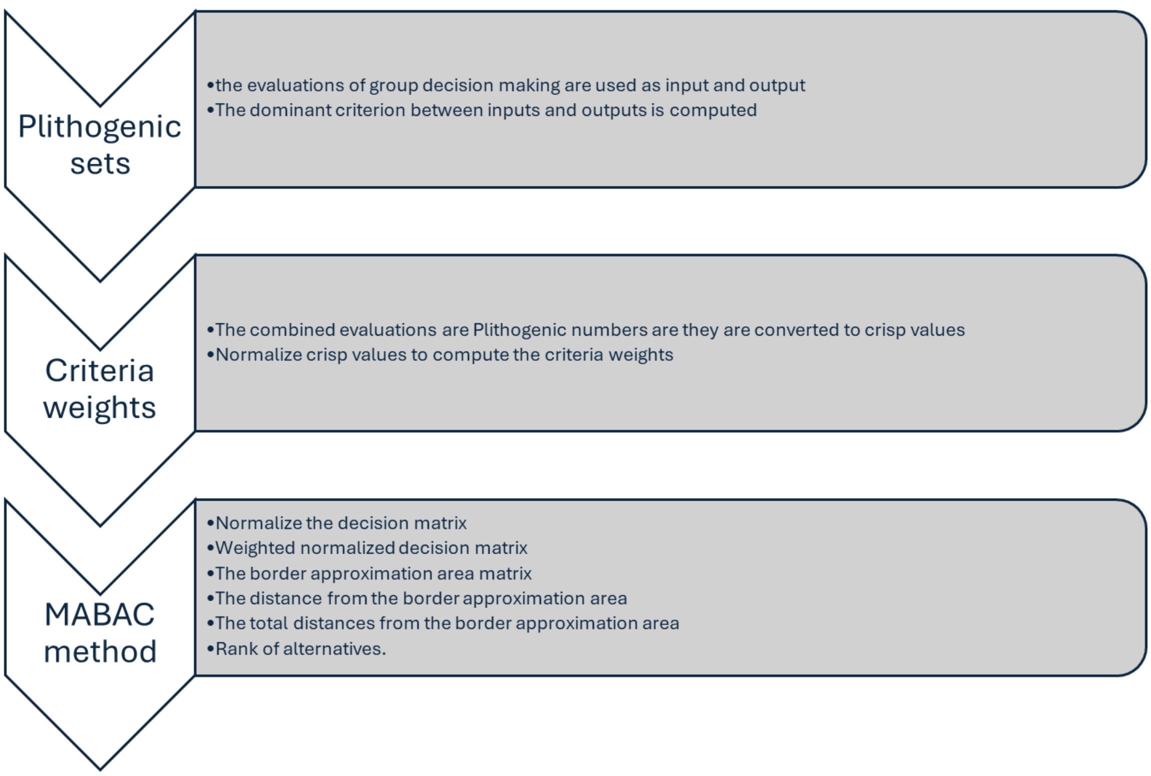

Figure 1. The steps of MABAC method under uncertainty environment.

3. The Multi-Attributive Border Approximation area Comparison (MABAC) method

This section shows the steps of the MABAC under the Plithogenic numbers to rank the alternatives and deal with vague information[20]. Figure 1 shows the steps of MABAC method under Plithogenic sets.

Normalize the decision matrix.

The normalized decision matrix is computed for positive and negative criteria such as:

$$l_{ij} = \frac{x_{ij} - \min x_i}{\max x_i - \min x_i}; i = 1, \dots, m; j = 1, \dots, n \quad (3)$$

$$l_{ij} = \frac{x_{ij} - \max x_i}{\min x_i - \max x_i}; i = 1, \dots, m; j = 1, \dots, n \quad (4)$$

Weighted normalized decision matrix

$$u_{ij} = w_j + l_{ij} w_j \quad (5)$$

The border approximation area matrix

$$g_j = \left(\prod_{i=1}^{m} u_{ij}\right)^{\frac{1}{m}} \quad (6)$$

The distance from the border approximation area

$$d_{ij} = u_{ij} - g_j \quad (7)$$

The total distances from the border approximation area.

$$K_i = \sum_{j=1}^{n} d_{ij} \quad (8)$$

The final rank of alternatives.

4. Application

This study evaluates the criteria and alternatives performance and importance with Plithogenic sets and MABAC method. The performance indicators are evaluated from a set of experts. Three experts are invited to evaluate seven criteria and 13 alternatives. The sets of criteria as:

C1: Financial Security and Assistance

C2: Quality of Care Facilities and Personnel

C3: Social Inclusion and Community Engagement

C4: Technological Integration in Care Services

C5: Accessibility of Services

C6: Health and Medical Support

C7: Emotional and Psychological Support

Step 1. Three experts evaluated the criteria and alternatives using the linguistic term. These terms are transformed into Plithogenic numbers as shown in Tables 1-3.

Step 2. The dominant criterion between inputs and outputs is computed. Step 3. We obtain the crisp values between inputs and outputs. Step 4. Normalize crisp values to compute the criteria weights. The criteria weights are shown in Figure 2.

Table 1. The opinion of first expert.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
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)
A_2	(0.95, 0.05, 0.05)	(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)	(0.10, 0.75, 0.85)
A_3	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)
A_4	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)
A_5	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)
A_6	(0.40, 0.70, 0.50)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)
A_7	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.40, 0.70, 0.50)
A_8	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)
A_9	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)
A_{10}	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)
A_{11}	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)
A_{12}	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)
A_{13}	(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)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)

Table 2. The opinion of second expert.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(0.50, 0.40, 0.60)	(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)
A_2	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)
A_3	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)
A_4	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
A_5	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)
A_6	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)
A_7	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)
A_8	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)
A_9	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
A_{10}	(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)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)
A_{11}	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)
A_{12}	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)
A_{13}	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)

Table 3. The opinion of third expert.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
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)
A_2	(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)	(0.40, 0.70, 0.50)	(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)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_4	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)
A_5	(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)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)
A_6	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)
A_7	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)
A_8	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)
A_9	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)
A_{10}	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_{11}	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)
A_{12}	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)
A_{13}	(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)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)

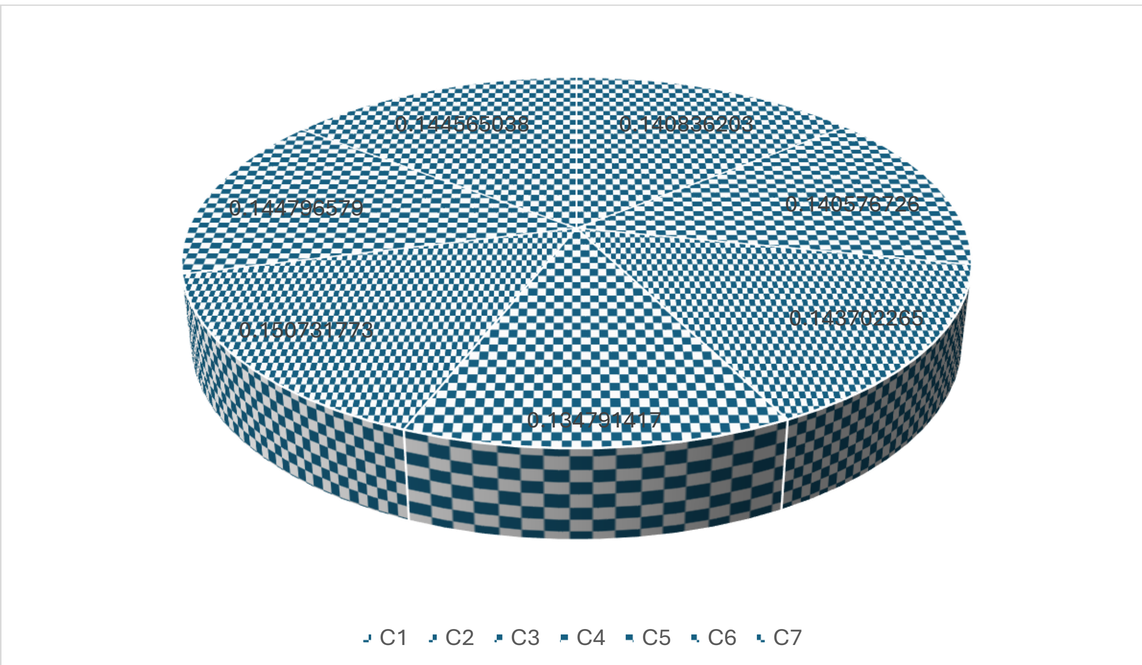

Figure 2. The criteria weights.

We normalize the decision matrix as shown in Table 4. Then we compute the weighted normalized matrix as shown in Table 5.

Table 4. The normalized matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0	0.162322	0.336178	0.591114	0.736936	1	1
A_2	0.510073	1	1	0.729845	0.495968	0.444643	0.158812
A_3	0.42076	0.250807	0.563016	0.666129	0.859148	0.241977	0.642511
A_4	0.365119	0.658812	0	0	0.530213	0	0.558586
A_5	0.802475	0.717398	0.677383	0	0.488952	0.927526	0.465946
A_6	0.48868	0.69327	0.74623	1	0.81108	0.960332	0.833844

A_7	0.475249	0.655423	0.496444	0.982584	0.768248	0.782141	0.784216
A_8	0.341328	0.642511	0.269322	0.91547	0.506859	0.600698	0.769246
A_9	0.833125	0	0.02276	0.167191	0.265996	0.39355	0
A_{10}	1	0.556085	0.947416	0.266927	0	0.71407	0.082392
A_{11}	0.254701	0.589897	0.762352	0.33659	0.488952	0.520806	0.658812
A_{12}	0.291587	0.631375	0.781223	0.399116	0.25144	0.796303	0.717398
A_{13}	0.249233	0.561491	0.781223	0.982584	1	1	0.747176

Table 5. The weighted normalized matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.140836	0.163395	0.192012	0.214468	0.261811	0.289593	0.28913
A_2	0.212673	0.281153	0.287405	0.233168	0.22549	0.209179	0.167524
A_3	0.200094	0.175834	0.224609	0.22458	0.280233	0.179834	0.23745
A_4	0.192258	0.23319	0.143702	0.134791	0.230652	0.144797	0.225317
A_5	0.253854	0.241426	0.241044	0.134791	0.224432	0.279099	0.211925
A_6	0.20966	0.238034	0.250937	0.269583	0.272987	0.283849	0.26511
A_7	0.207769	0.232714	0.215042	0.267235	0.266531	0.258048	0.257935
A_8	0.188908	0.230899	0.182404	0.258189	0.227132	0.231776	0.255771
A_9	0.25817	0.140577	0.146973	0.157327	0.190826	0.201781	0.144565
A_{10}	0.281672	0.218749	0.279848	0.170771	0.150732	0.248192	0.156476
A_{11}	0.176707	0.223502	0.253254	0.180161	0.224432	0.220208	0.239806
A_{12}	0.181902	0.229333	0.255966	0.188589	0.188632	0.260099	0.248276
A_{13}	0.175937	0.219509	0.255966	0.267235	0.301464	0.289593	0.252581

The border approximation area matrix is computed and the distance from the border approximation area is computed. We compute the total distances from the border approximation area. Final the rank of alternatives in Figure 3.

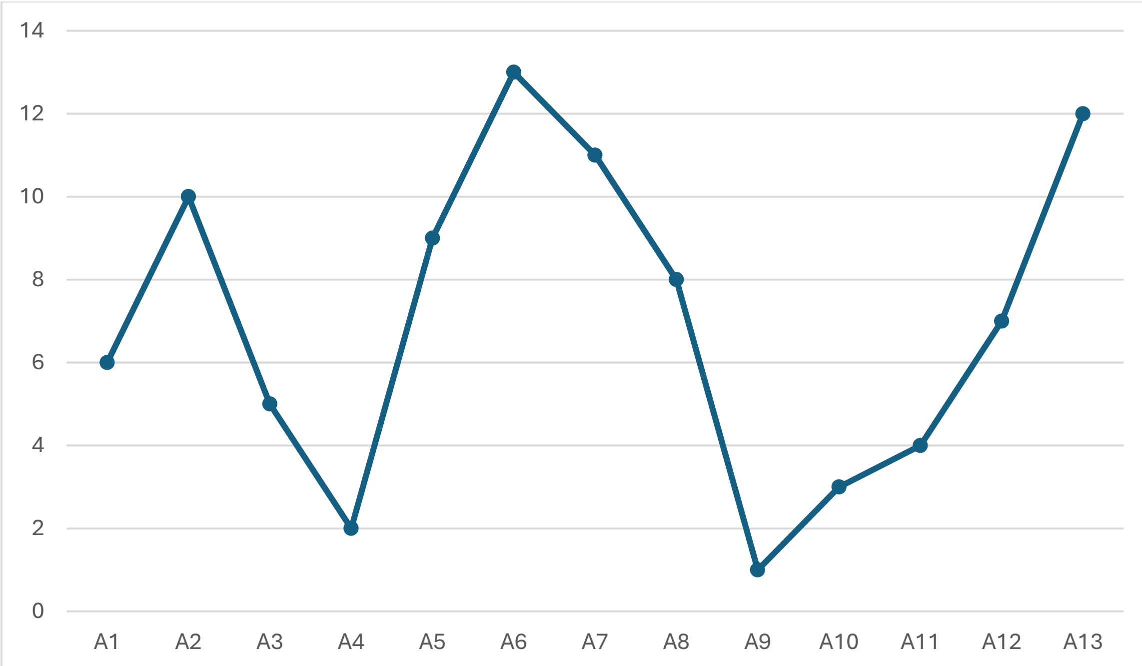

Figure 3. The rank of alternatives.

5. Analysis

This section shows the sensitivity analysis to show the different rank of alternatives under different weights. We proposed five cases in criteria weights in Figure 4. Then we applied the MABAC method under these weights. Table 6 shows the rank of alternatives. The results show the rank of alternatives is stable under different criteria weights.

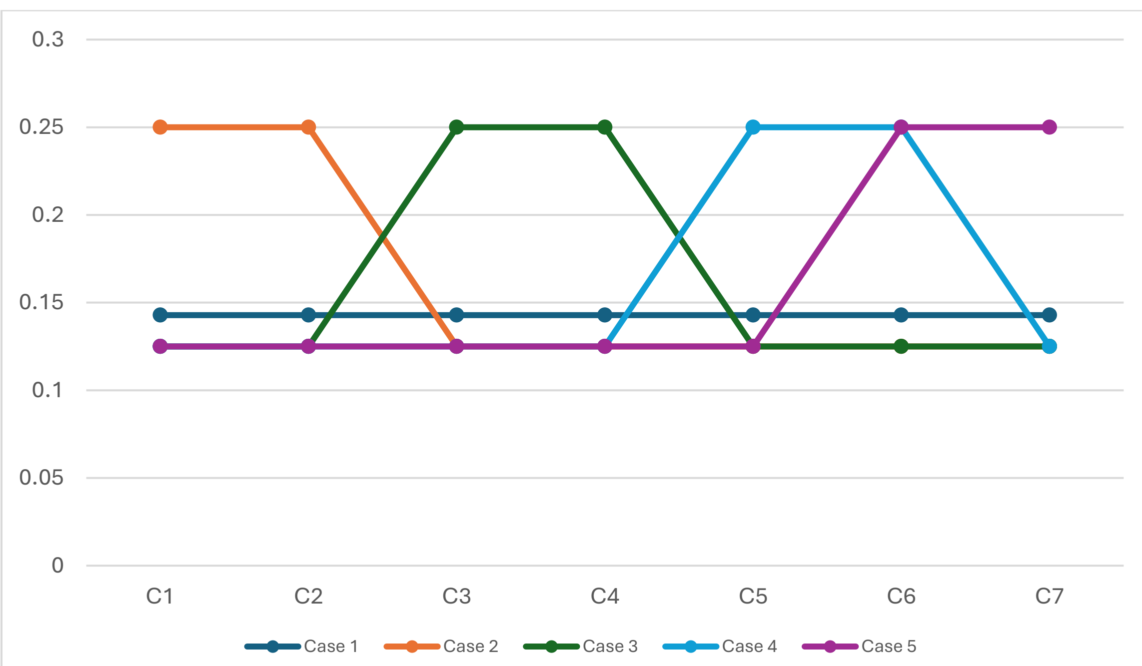

Figure 4. The different criteria weights.

Table 6. The rank of alternatives under sensitivity analysis.

	Case 1	Case 2	Case 3	Case 4	Case 5
A_1	6	3	4	10	10
A_2	10	10	10	8	6
A_3	5	4	7	5	4
A_4	2	2	2	2	2
A_5	9	9	5	9	9
A_6	13	13	13	12	13
A_7	11	11	11	11	11
A_8	8	7	9	7	8
A_9	1	1	1	1	1
A_{10}	3	8	6	3	3
A_{11}	4	5	3	4	5
A_{12}	7	6	8	6	7
A_{13}	12	12	12	13	12

6. Conclusions

In this paper a performance evaluation methodology for ranking the elderly care security services with a set of criteria and alternatives. Three experts have evaluated the criteria and alternatives. Then we used the plithogenic numbers instead of the linguistic terms. Then these numbers are combined into a single matrix. Then we obtain crisp values. The Plithogenic numbers are combined with the MCDM methodology such as MABAC method to rank the alternatives. Seven criteria and 13 alternatives are collected to select the best alternatives. The results show the alternative 13 has the highest rank and alternative 9 has the lowest rank. The sensitivity analysis was conducted to show the different ranks of alternatives under different weights. Five cases of criteria weights are conducted. The results show the rank of the proposed methodology is stable under different weights.

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