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An Integrated Pythagorean Neutrosophic DEMATEL- Grey Relational Analysis Framework for Assessing Recent Technological Advancements in Maternal Healthcare

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Abstract:

This study proposes a novel methodology that integrates the Decision making trial and evolution laboratory (DEMATEL) technique and Grey relational analysis (GRA) in a Pythagorean neutrosophic environment. This multi-criteria decision-making approach uses the DEMATEL technique to analyze the weights of the criteria and Grey relational analysis to prioritize the alternatives. The proposed approach is utilized to evaluate the most recent technological advancements in maternity healthcare, along with a pertinent numerical example.

Keywords: Neutrosophic sets, Pythagorean Neutrosophic sets, DEMATEL, Grey Relational Analysis, Medical Technology Assessment.

1. Introduction

Neutrosophic set (NS) was introduced by Florentin Smarandache [3] in 1998. The neutrosophic set generalizes the concepts of the classic set, fuzzy set,interval-valued fuzzy set, Intuitionistic fuzzy set. The concept of Pythagorean fuzzy sets is introduced by Yagar and Abbasov[6]. Zhang and Xu [7] established the general mathematical form of Pythagorean fuzzy sets. The Pythagorean Neugosophic Set (PNS), which combines Pythagorean fuzzy sets and neutrosophic sets, is one of the most recent extensions of the theory of neutrosophic sets. Recently, many MCDM approaches have been developed in the context of the Pythagorean Neutrosophic environment.

Recently, Feng L et al.[9] developed the single valued neutrosophic DEMATEL multi criteria model and applied it to select the transport service provider. R. Jansi et al. [10] proposed the Correlation Measure for Pythagorean Neutrosophic sets with T and F dependent neutrosophic components. Mamites L et al. [11] developed the framework for neutrosophic DEMATEL and applied it to factors influencing teaching quality in universities. P. H. Nguyen et al. [12] defined a grey MCDM based on DEMATEL model and investigate the real estate evaluation and selection problems. Prema and Radha [13] defined a Generalized neutrosophic pythagorean set. J N. Ismail et al. [13] developed the integrated novel framework for pythagorean neutrosophic set with DEMATEL method.

This paper presents a novel approach to solve multi-criteria decision making problem by integrating the DEMATEL method and Grey Relational Analysis method. The final results are obtained from the pythagorean neutrosophic grey relational degree based on the maximum score value. This paper consists the following sections: Section 2 contains basic definitions related to pythagorean neutrosophic set . The proposed method is presented in section 3. The case study and illustration are discussed in section 4. Conclusion appear in section 5.

2. Preliminaries

Definition 2.1

Let X be non-emty set. A pythagorean Neutrosophic set with T and F as dependent neutrosophic components A on X is an object of the form

$$A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle \mid x \in X\}$$

Where $T_A(x), I_A(x), F_A(x)$ are the truth, indeterminacy and falsity membership respectively such that $T, I, F \in [0,1]$. Here with T and F are dependent components, then for all x in X;

$T + F \leq 1,\ 0 \leq T^2 + F^2 \leq 1,\ 0 \leq T^2 + I^2 + F^2 \leq 2$.

3. The Integrated PNS DEMATEL and GRA procedures

In this section, an integerated pythagorean neutropsohic DEMATEL-GRA approach is developed for solving MCDM problem. DEMATEL method is employed to identify the weights of criteria set. The GRA technique is used to evaluate alternatives. Let us consider that this approach is modified from P. H. Nguyen and J. F. Tsai [12].

3.1 The PNS Decision Making Trial and Evaluation Laboratory method(DEMATEL)

Step 1: Create the initial direct influence matrix based on decision-makers preferences by using the Pythagorean neytrosphic linguistic variable score value. The matrix contains PNS in the form $x_{ij}^k = \langle T_{ij}, I_{ij}, F_{ij}\rangle$

$$X_D^k = \begin{bmatrix} 0 & x_{12}^k & \cdots & x_{1n}^k \\ x_{21}^k & 0 & \cdots & x_{2n}^k \\ \vdots & \vdots & 0 & \vdots \\ x_{n1}^k & x_{n2}^k & \cdots & 0 \end{bmatrix} \text{----- (1)}$$

Where $T_{ij}, I_{ij}, F_{ij} \in [0,1]$ and $0 \leq {T_{ij}}^2 + {T_{ij}}^2 + {T_{ij}}^2 \leq 2$, $i = 1,2,\ldots,n,\ j = 1,2,\ldots,m$.

Step 2: Construct the total average crisp matrix $B_{ij.}$ The formula for deneutrosophicate to convert the pythagorean neutrosophic number to a crisp value is applied as follows,

$$B_{ij} = \frac{1T_A(x) + 0.5I_A(x)}{1.5} \text{----- (2)}$$

Step 3: The direct influence matrix is being normalized. The formula for constructing the normalized direct-influenced matrix Z = $[Z_{ij}]_{m\times n}$is as follows,

$$Z = \frac{\mathcal{B}}{s} \text{ ----- (3)}$$

Where, $s = \max_{1 \le i \le n} \sum_{j=1}^{n} b_{ij}$. In the matrix Z, every entry complies with $0 \le z_{ij} \le 1$.

Step 4: Create the total-influence matrix T_{ij}. The total relation matrix T is computed from the normalized matrix Z using,

$$T = Z(I - Z)^{-1} \text{ ----- (4)}$$

Where I is identity matrix.

Step 5: In this step, the vectors R and C representing the sum of the rows and columns that are calculated from the total- influence matrix T using the following formulas.

$$R = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \text{ ----- (5)}$$

$$C = [c_i]_{1\times n} = \left[\sum_{j=1}^{n} t_{ij}\right]_{1\times n} \text{ ----- (6)}$$

Step 6: Creating the value of $(R + C)$ and $(R - C)$. Accordingly, these values represent the importance and relation values, respectively.

Step 7: Calculating criteria weights using the results of DEMATEL. The criteria are determined by using,

$$W = [(R + C)^2 + (R - C)^2]^{1/2} \text{ ----- (7)}$$

$$W^{nor} = W / \sum_{i-1}^{n} W_i \text{ ----- (8)}$$

Where W^{nor} is normalized weights of criteria.

3.2 The PNS Grey Relational Analysis (GRA)

Step 1: Construct the decision matrix using Pythagorean neutrosophic linguistic variable. The PNS criterion matrix is a matrix in which the performance value of x_{ij} could be organized. The matrix contains PNS in the form $x_{ij}^{k} = \langle T_{ij}, I_{ij}, F_{ij} \rangle$

$$X_G^k = \begin{bmatrix} x_{11}^k & x_{12}^k & \cdots & x_{1m}^k \\ x_{21}^k & x_{22}^k & \cdots & x_{2m}^k \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1}^k & x_{n2}^k & \cdots & x_{nm}^k \end{bmatrix}$$

Where $T_{ij}, I_{ij}, F_{ij} \in [0,1]$ and $0 \le {T_{ij}}^2 + {I_{ij}}^2 + {F_{ij}}^2 \le 2$, for $i = 1,2,\ldots,n,\ j = 1,2,\ldots,m$.

Step 2: i) Determined the ideal pythagorean neutrosophic estimates reliability solution (IPNERS)

$$Q_{ij}^{+} = \langle {q_{s}}_{1}^{+}, {q_{s}}_{2}^{+}, \ldots, {q_{s}}_{n}^{+} \rangle \text{ ----- (9)}$$

Q_s^+ is a solution presented by ${q_{s}}_{1}^{+} = \langle T_j^+, I_j^+, F_j^+ \rangle$, where $T_j^+ = \max_i \{T_{ij}\}$, $I_j^+ = \min_i \{I_{ij}\}$ and $F_j^+ = \min_i \{F_{ij}\}$ in the pythagorean neutrosophic decision matrix $x_{ij}^k = \langle T_{ij}, I_{ij}, F_{ij} \rangle$, for $i = 1,2,\ldots,n,\ j = 1,2,\ldots,m$.

ii) Determined the ideal pythagorean neutrosophic estimates un-reliability solution (IPNEURS).

$$Q_{ij}^{-} = \langle q_{s_1}^{-}, q_{s_2}^{-}, \ldots, q_{s_n}^{-} \rangle \text{ ----- } (10)$$

Q_s^- is a solution presented by $q_{s_1}^{-} = \langle T_j^-, I_j^-, F_j^- \rangle$, where $T_j^- = \min_i \{T_{ij}\}$, $I_j^- = \max_i \{I_{ij}\}$ and $F_j^- = \max_i \{F_{ij}\}$ in the pythagorean neutrosophic decision matrix $x_{ij}^k = \langle T_{ij}, I_{ij}, F_{ij} \rangle$, for $i = 1,2,\ldots,n$, $j = 1,2,\ldots,m$.

Step 3: Calculate the pythagorean neutrosophic grey relational coefficient.The formula for the grey relational coefficient for every alternative derived from IPNERS is as follows:

$$G_{ij}^{+} = \frac{\min_i \min_j \Delta_{ij}^{+} + \rho \max_i \max_j \Delta_{ij}^{+}}{\Delta_{ij}^{+} + \rho \max_i \max_j \Delta_{ij}^{+}} \text{ ----- } (11)$$

Where $\Delta_{ij}^{+} = d(q_{s_j}^{+}, q_{s_{ij}})$ for $i = 1,2,\ldots,n$, $j = 1,2,\ldots,m$.

The formula for the grey relational coefficient for every alternative derived from IPNEURS is as follows:

$$G_{ij}^{-} = \frac{\min_i \min_j \Delta_{ij}^{-} + \rho \max_i \max_j \Delta_{ij}^{-}}{\Delta_{ij}^{+} + \rho \max_i \max_j \Delta_{ij}^{-}} \text{ ----- } (12)$$

Where $\Delta_{ij}^{-} = d(q_{s_{ij}}, q_{s_j}^{-})$ for $i = 1,2,\ldots,n$, $j = 1,2,\ldots,m$.

$\rho \in [0,1]$ is also known as the identifying or distinguishing coefficient, The large range of grey relationship coefficients is reflected in the smaller value of the distinguishing coefficient.

Generally, $\rho = 0.5$ is set for decision-making situation.

Step 4: Compute the degree of grey relational coefficient of each alternative from IPNERS and IPNEURS respectively as follows:

$$\chi_i^{+} = \sum_{j=1}^{n} w_j \chi_{ij}^{+}, \; i = 1,2,\ldots,n \text{----- } (13)$$

$$\chi_i^{-} = \sum_{j=1}^{n} w_j \chi_{ij}^{-}, \; i = 1,2,\ldots,n \text{----- } (14)$$

Step 5: Compute the relative relaional degree of each alternative by using the following equation,

$$R_i = \frac{\chi_i^{+}}{\chi_i^{+} + \chi_i^{-}}, \text{ for } i = 1,2,\ldots,n \text{----- } (15)$$

Step 6: Rank the alternatives by using relative relational degree. The highest value of $R_i$indicates the most important alternative.

4. Medical Technology Assessment Problem

This section presents a numerical example that demonstrates the applicability of the proposed multi-criteria decision making approach. The focus of this study is to investigate the most recent technological developments in maternal healthcare. To develop this MCDM problem, eight alternatives with eight relevant criteria are utilized. The alternatives are examined with input from five experts, and the opinions of the experts are used to form the decision matrix. The role of modern technology in maternity healthcare is explained in the following:

Remote monitoring devices

Remote monitoring devices play an important role in maternal health care by providing real-time data and allowing health care providers to monitor pregnant women's health outside of traditional clinical settings. Remote monitoring allows continuous tracking of health parameters, allowing early detection of complications such as gestational hypertension, preeclampsia, and other high-risk diseases. These devices will significantly contribute to improving maternal health care by increasing accessibility, enabling early detection of complications, and promoting patient engagement.

IoMT and wearable health devices

The Internet of Medical Things (IoMT) is playing an important role in transforming and improving maternal health care by leveraging technology to monitor, manage, and improve the health of pregnant women. IoMT devices generate rich data that can be analyzed to identify patterns and predict potential complications, enabling proactive interventions to reduce risks during pregnancy. Wearable devices equipped with sensors can monitor fetal movement and heart rate, providing real-time data to health care providers and alerting them to potential problems.

Virtual Reality (VR) and Augmented Reality (AR)

VR and AR technologies are being explored for educational purposes, providing pregnant women with immersive experiences to learn more about pregnancy, childbirth, and postnatal care. These are used to train healthcare professionals such as obstetricians, midwives and nurses to manage different aspects of maternal health. These technologies provide a dynamic way to present information, making the learning process more engaging and memorable.

Artificial intelligence(AI)

AI algorithms can vividly examine and catagorise the large datasets, including electronic medical records and patient histories, to identify patterns and predict the risk of complications during pregnancy. AI-powered monitoring systems can analyze fetal heart rate patterns, uterine contractions, and other parameters to assess fetal health. Continuous AI-powered monitoring detects abnormalities and potential signs of stress, enabling timely intervention.

Mobile-Health applications (mHealth)

Mobile apps can provide personalized information, reminders, and guidance to pregnant women. Some apps also include features to track symptoms, diet, and exercise. The app helps women monitor the progress of their pregnancy by providing information about fetal development, maternal changes, and weekly milestones. These applications cover a wide range of functionality, from tracking the progress of a pregnancy to providing educational content and facilitating communication with healthcare providers.

Telehealth and Telemedicine

Telemedicine platforms allow pregnant women to consult virtually with health care providers, reducing the need for in-person visits, especially when mobility is difficult. Medical professionals can use telemedicine solutions to remotely monitor important indicators such as blood pressure, weight, and fetal heart rate. Telehealth supports mental health services, including counseling and support groups for pregnant women suffering from anxiety, depression, and other emotional issues. These platforms allow healthcare providers to update prescriptions for pre-natal vitamins and medications without an in-person visit.

3D/4D Ultrasound imaging

3D (three-dimensional) and 4D (four-dimensional) ultrasound imaging is an advanced medical imaging technique used in obstetrics and gynecology to visualize the fetus within the uterus. 3D ultrasound creates a three-dimensional image of the fetus, showing the baby's anatomy in more detail and realistically. 4D ultrasound adds the dimension of time and provides a real-time video sequence of 3D images. This means that in addition to the fetal structure, you can also see the fetal movements. The use of 3D and 4D ultrasound is reserved for specific clinical indications, such as assessing fetal abnormalities or confirming suspected problems identified during routine prenatal examinations.

Nanotechnology

Often, Nanotechnology offers innovative solutions to address challenges related to diagnostics, drug delivery, imaging, and monitoring. Nano sensors can be developed for early detection of biomarkers associated with pregnancy complications. Nano particles such as quantum dots and magnetic nano particles can be used for advanced imaging techniques. This allows for better visualization of fetal development and more accurate diagnosis of abnormalities. It can be used to improve the supply of essential and micro-nutrients in pregnant women, correct nutritional deficiencies, and support fetal development.

4.1 Illustrative Example:

Assume that $A = (a_1, a_2, \ldots, a_n)$ be a discrete set of alternatives, $C = (c_1, c_2, \ldots, c_m)$ be a set of factors or criteria under consideration in a MCDM problem. The rating of performance value of alternative a_i, $i = 1,2,\ldots,n$ with respect to the criteria set $c_j, j = 1,2,\ldots,m$ and is represented by pythagorean neutrosophic number, $x_{ij}^k = \langle T_{ij}, I_{ij}, F_{ij} \rangle$, Where $T_{ij}, I_{ij}, F_{ij} \in [0,1]$ and $0 \leq {T_{ij}}^2 + {I_{ij}}^2 + {F_{ij}}^2 \leq 2$, for $i = 1,2,\ldots,n$, $j = 1,2,\ldots,m$. This integrated pythagorean neutrosophic MCDM problem evaluate the performance of latest technology in maternal health care.

Let us consider the alternatives $A = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8)$,

a_1- Remote monitoring devices, a_2- IoMT and wearable health devices, a_3- Virtual reality and Augmented reality, a_4- Artificial intelligence(AI), a_5- M-Health applications, a_6- Telehealth and Telemedicine, a_7- 3D/4D Ultrasound imaging, a_8- Nanotechnology.

Let us consider the alternatives $C = (c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8)$,

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c_1 - Accuracy and Reliability, c_2 - Security and Privacy, c_3 - Interoperability, c_4 - User-Friendliness

c_5 - Scalability and Sustainability, c_6 - Cost-Effectiveness, c_7 - Clinical Outcomes, c_8 - Accessibility

4.1.1 The Pythagorean Neutrosophic DEMATEL Procedure

Table 1: The Pythagorean Neutrosophic Linguistic variable

Linguistic variable	**Pythagorean Neutrosophic Number**	**Score**
No Influence	⟨0.1,0.7,0.9⟩	1
Low Influence	⟨0.2,0.6,0.8⟩	2
Medium Low Influence	⟨0.3,0.5,0.7⟩	3
Medium Influence	⟨0.5,0.4,0.3⟩	4
Medium High Influence	⟨0.6,0.5,0.4⟩	5
High Influence	⟨0.8,0.3,0.1⟩	6
Very High Influence	⟨0.9,0.2,0.1⟩	7

Table 2: Initial direct-relation matrix, X^k

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
C1	0	3	5	2	6	4	7	1
C2	2	0	3	1	4	5	6	3
C3	6	3	0	7	5	4	2	3
C4	2	1	6	0	4	3	1	7
C5	7	5	4	3	0	2	6	4
C6	5	6	7	5	4	0	5	6
C7	7	5	6	3	5	4	0	2
C8	1	2	1	5	3	7	4	0

Table 3: Initial decision matrix, X^k

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
C1	0	⟨0.3,0.5,0.7⟩	⟨0.6,0.5,0.4⟩	⟨0.2,0.6,0.8⟩	⟨0.8,0.3,0.1	⟨0.5,0.4,0.3⟩	⟨0.9,0.2,0.1⟩	⟨0.1,0.7,0.9⟩
C2	⟨0.2,0.6,0.8⟩	0	⟨0.3,0.5,0.7⟩	⟨0.1,0.7,0.9⟩	⟨0.5,0.4,0.3	⟨0.6,0.5,0.4⟩	⟨0.8,0.3,0.1⟩	⟨0.3,0.5,0.7⟩
C3	⟨0.8,0.3,0.1⟩	⟨0.3,0.5,0.7⟩	0	⟨0.9,0.2,0.1⟩	⟨0.6,0.5,0.4	⟨0.5,0.4,0.3⟩	⟨0.2,0.6,0.8⟩	⟨0.3,0.5,0.7⟩
C4	⟨0.2,0.6,0.8⟩	⟨0.1,0.7,0.9⟩	⟨0.8,0.3,0.1⟩	0	⟨0.5,0.4,0.3	⟨0.3,0.5,0.7⟩	⟨0.1,0.7,0.9⟩	⟨0.9,0.2,0.1⟩
C5	⟨0.9,0.2,0.1⟩	⟨0.6,0.5,0.4⟩	⟨0.5,0.4,0.3⟩	⟨0.3,0.5,0.7⟩	0	⟨0.2,0.6,0.8⟩	⟨0.8,0.3,0.1⟩	⟨0.5,0.4,0.3⟩
C6	⟨0.6,0.5,0.4⟩	⟨0.8,0.3,0.1⟩	⟨0.9,0.2,0.1⟩	⟨0.6,0.5,0.4⟩	⟨0.5,0.4,0.3	0	⟨0.6,0.5,0.4⟩	⟨0.8,0.3,0.1⟩
C7	⟨0.9,0.2,0.1⟩	⟨0.6,0.5,0.4⟩	⟨0.8,0.3,0.1⟩	⟨0.3,0.5,0.7⟩	⟨0.6,0.5,0.4	⟨0.5,0.4,0.3⟩	0	⟨0.2,0.6,0.8⟩
C8	⟨0.1,0.7,0.9⟩	⟨0.2,0.6,0.8⟩	⟨0.1,0.7,0.9⟩	⟨0.6,0.5,0.4⟩	⟨0.3,0.5,0.7	⟨0.9,0.2,0.1⟩	⟨0.5,0.4,0.3⟩	0

Table 4: The Aggregated crisp Matrix, B_{ij}

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0.3667	0.5667	0.3333	0.6333	0.4667	0.6667	0.3000
C2	0.3333	0	0.3667	0.3000	0.4667	0.5667	0.6333	0.3667
C3	0.6333	0.3667	0	0.6667	0.5667	0.4667	0.3333	0.3667
C4	0.3333	0.3000	0.6333	0	0.4667	0.3667	0.3000	0.6667
C5	0.6667	0.5667	0.4667	0.3667	0	0.3333	0.6333	0.4667
C6	0.5667	0.6333	0.6667	0.5667	0.4667	0	0.5667	0.6333
C7	0.6667	0.5667	0.6333	0.3667	0.5667	0.4667	0	0.3333
C8	0.3000	0.3333	0.3000	0.5667	0.3667	0.6667	0.4667	0

Table 5: The Normalized Matrix, Z_{ij}

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	0.0894	0.1382	0.0812	0.1544	0.1138	0.1626	0.0731
C2	0.0812	0	0.0894	0.0731	0.1138	0.1382	0.1544	0.0894
C3	0.1544	0.0894	0	0.1626	0.1382	0.1138	0.0812	0.0894
C4	0.0812	0.0731	0.1544	0	0.1138	0.0894	0.0731	0.1626
C5	0.1626	0.1382	0.1138	0.0894	0	0.0812	0.1544	0.1138
C6	0.1382	0.1544	0.1626	0.1382	0.1138	0	0.1382	0.1544
C7	0.1626	0.1382	0.1544	0.0894	0.1382	0.1138	0	0.0812
C8	0.0731	0.0812	0.0731	0.1382	0.0894	0.1626	0.1138	0

Table 6: The Total Influence Matrix, T_{ij}

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	0,5265	0.5524	0.6571	0.5444	0.6582	0.5891	0.6698	0.5284
C2	0.5576	0.4336	0.5747	0.5003	0.5819	0.5721	0.6218	0.5067
C3	0.6570	0.5497	0.5377	0.6129	0.6462	0.5910	0.6052	0.5482
C4	0.5479	0.4911	0.6175	0.4319	0.5747	0.5289	0.5457	0.5634
C5	0.6779	0.6026	0.6508	0.5626	0.5385	0.5803	0.6802	0.5730
C6	0.7365	0.6864	0.7718	0.6791	0.7196	0.5812	0.7452	0.6811
C7	0.6971	0.6188	0.7018	0.5799	0.6780	0.6210	0.5629	0.5633
C8	0.5403	0.5007	0.5560	0.5498	0.5537	0.5854	0.5789	0.4238

Table 7: Ranking of Criteria

Criteria	R	C	R+C	R-C	Cause/Effect
C1	4.7268	4.9108	9.6366	-0.1850	Effect
C2	4.3487	4.4352	8.7839	-0.0865	Effect
C3	4.7178	5.0674	9.7852	-0.3496	Effect
C4	4.3011	4.4607	8.7618	-0.1596	Effect
C5	4.8659	4.9506	9.8165	-0.0847	Effect
C6	5.6008	4.6492	10.2500	0.9516	Cause
C7	5.0228	5.0092	10.0325	0.0131	Cause
C8	4.2886	4.3879	8.6765	-0.0993	Effect

Table 8: Weights of the Criteria

Criteria	Weights (W)	Normalized Weights (W^{nor})
C1	9.6383	0.1271
C2	8.7843	0.1158
C3	9.7914	0.1292
C4	8.7632	0.1156
C5	9.8168	0.1295
C6	10.2940	0.1358
C7	10.0325	0.1324
C8	8.6770	0.1145

4.1.2 The Pythagorean Neutrosophic GRA Procedure

Table 9:The Pythagorean Neutrosophic Linguistic Variable

Linguistic variable	Pythagorean Neutrosophic Number
Extremely Less Importance	$\langle 0.1,0.8,0.9\rangle$
Strongly Less Importance	$\langle 0.2,0.6,0.7\rangle$
Moderately Less Importance	$\langle 0.3,0.5,0.6\rangle$
Equally Importance	$\langle 0.5,0.3,0.2\rangle$
Moderately More Importance	$\langle 0.7,0.4,0.3\rangle$
Strongly More Importance	$\langle 0.8,0.3,0.2\rangle$
Extremely More Importance	$\langle 0.9,0.2,0.1\rangle$

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Table 10: The Decision Matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	⟨0.7,0.4,0.3⟩	⟨0.3,0.5,0.6⟩	⟨0.8,0.3,0.2⟩	⟨0.7,0.4,0.3⟩	⟨0.5,0.3,0.2	⟨0.3,0.5,0.6⟩	⟨0.7,0.4,0.3⟩	⟨0.8,0.3,0.2⟩
C2	⟨0.8,0.3,0.2⟩	⟨0.8,0.3,0.2⟩	⟨0.7,0.4,0.3⟩	⟨0.8,0.3,0.2⟩	⟨0.7,0.4,0.3	⟨0.1,0.8,0.9⟩	⟨0.9,0.2,0.1⟩	⟨0.7,0.4,0.3⟩
C3	⟨0.7,0.4,0.3⟩	⟨0.8,0.3,0.2⟩	⟨0.8,0.3,0.2⟩	⟨0.7,0.4,0.3⟩	⟨0.5,0.3,0.2	⟨0.2,0.6,0.7⟩	⟨0.7,0.4,0.3⟩	⟨0.8,0.3,0.2⟩
C4	⟨0.9,0.2,0.1⟩	⟨0.8,0.3,0.2⟩	⟨0.8,0.3,0.1⟩	⟨0.7,0.4,0.3⟩	⟨0.8,0.3,0.2	⟨0.5,0.3,0.2⟩	⟨0.9,0.2,0.1⟩	⟨0.3,0.5,0.6⟩
C5	⟨0.5,0.3,0.2⟩	⟨0.7,0.4,0.3⟩	⟨0.7,0.4,0.3⟩	⟨0.9,0.2,0.1⟩	⟨0.3,0.5,0.6	⟨0.2,0.6,0.7⟩	⟨0.5,0.3,0.2⟩	⟨0.8,0.3,0.2⟩
C6	⟨0.8,0.3,0.2⟩	⟨0.9,0.2,0.1⟩	⟨0.8,0.3,0.2⟩	⟨0.6,0.5,0.4⟩	⟨0.7,0.4,0.3	⟨0.3,0.5,0.6⟩	⟨0.8,0.3,0.2⟩	⟨0.5,0.3,0.2⟩
C7	⟨0.8,0.3,0.2⟩	⟨0.7,0.4,0.3⟩	⟨0.7,0.4,0.3⟩	⟨0.5,0.3,0.2⟩	⟨0.8,0.3,0.2	⟨0.1,0.8,0.9⟩	⟨0.9,0.2,0.1⟩	⟨0.2,0.6,0.7⟩
C8	⟨0.7,0.4,0.3⟩	⟨0.5,0.3,0.2⟩	⟨0.2,0.6,0.7⟩	⟨0.3,0.5,0.6⟩	⟨0.7,0.4,0.3	⟨0.2,0.6,0.7⟩	⟨0.8,0.3,0.2⟩	⟨0.7,0.4,0.3⟩

Step 2: Determination of the ideal pythagorean neutrosophic estimates reliability solution (IPNERS). $Q_{ij}^{+} = \langle \max_i\{T_{ij}\}, \min_i\{I_{ij}\}, \min_i\{F_{ij}\}\rangle$

$$Q_{ij}^{+} = [\langle 0.9,0.2,0.1\rangle, \langle 0.9,0.2,0.1\rangle, \langle 0.8,0.3,0.2\rangle, \langle 0.9,0.2,0.1\rangle, \langle 0.8,0.3,0.2\rangle, \langle 0.5,0.3,0.2\rangle, \langle 0.9,0.2,0.1\rangle, \langle 0.8,0.3,0.2\rangle]$$

Determination of the ideal pythagorean neutrosophic estimates reliability solution (IPNEURS).
$Q_{ij}^{+} = \langle \min_i\{T_{ij}\}, \max_i\{I_{ij}\}, \max_i\{F_{ij}\}\rangle$

$$Q_{ij}^{-} = [\langle 0.5,0.4,0.3\rangle, \langle 0.3,0.5,0.6\rangle, \langle 0.2,0.6,0.7\rangle, \langle 0.3,0.5,0.6\rangle, \langle 0.3,0.5,0.6\rangle, \langle 0.1,0.8,0.9\rangle, \langle 0.5,0.4,0.3\rangle, \langle 0.2,0.6,0.7\rangle]$$

Step 3: Calculaion of the Pythagorean neutrosophic Grey relational coefficient of each alternative from IPNERS

Table 11: Grey relational coefficient from IPNERS

$G_{ij}{}^{+}$	C1	C2	C3	C4	C5	C6	C7	C8
A1	0.5714	0.3636	1.0000	0.5714	0.7273	0.5000	0.5714	1.0000
A2	0.7273	0.7273	0.7273	0.7273	0.7273	0.3333	1.0000	0.7273
A3	0.5714	0.7273	1.0000	0.5714	0.7273	0.4211	0.5714	1.0000
A4	1.0000	0.7273	1.0000	0.5714	1.0000	1.0000	1.0000	0.4211
A5	0.5714	0.5714	0.7273	1.0000	0.4211	0.4211	0.5714	1.0000
A6	0.7273	1.0000	1.0000	0.7273	0.7273	0.5000	0.7273	0.7273
A7	0.7273	0.5714	0.7273	0.5714	1.0000	0.3333	1.0000	0.3636
A8	0.5714	0.5714	0.3636	0.3636	0.7273	0.4211	0.7273	0.7273

Calculation of the Pythagorean neutrosophic grey relational coefficient of each alternative from IPNEURS

Table 12: Grey relational coefficient from IPNEURS

G_{ij}^{+}	C1	C2	C3	C4	C5	C6	C7	C8
A1	0.8000	1.0000	0.3636	0.5000	0.5000	0.5000	0.8000	0.3636
A2	0.6154	0.4211	0.4211	0.4211	0.5000	1.0000	0.5000	0.4211
A3	0.8000	0.4211	0.3636	0.5000	0.5000	0.6154	0.8000	0.3636
A4	1.0000	0.4211	0.3636	0.5000	0.4211	0.3333	0.5000	0.7273
A5	0.8000	0.5000	0.4211	0.3636	1.0000	0.6154	0.8000	0.3636
A6	0.6154	0.3636	0.3636	0.4211	0.5000	0.5000	0.6154	0.4211
A7	0.6154	0.5000	0.4211	0.5000	0.4211	1.0000	0.5000	1.0000
A8	0.8000	0.5000	1.0000	1.0000	0.5000	0.6154	0.6154	0.4211

Step 4: Determine the degree of pythagorean neutrosophic grey relational co-efficient of each alternative from IPNERS and IPNEURS. The pythagorean neutrosophic grey relational co-efficient corresponding to IPNERS is obtained by using equation:

$$\chi_1^+ = 0.6623; \chi_2^+ = 0.7098;\ \chi_3^+ = 0.6937, \chi_4^+ = 0.8526,$$

$$\chi_5^+ = 0.6501, \chi_6^+ = 0.7632, \chi_7^+ = 0.6675, \chi_8^+ = 0.5587$$

The pythagorean neutrosophic grey relational co-efficient corresponding to IPNEURS is obtained by using equation:

$$\chi_1^- = 0.6623; \chi_2^- = 0.7098;\ \chi_3^- = 0.6937, \chi_4^- = 0.8526,$$

$$\chi_5^- = 0.6501, \chi_6^- = 0.7632, \chi_7^- = 0.6675, \chi_8^- = 0.5587$$

Step 5: Calculate the grey relative relational degree by using equation as follows:

$$R_1 = 0.5237, R_2 = 0.5657, R_3 = 0.5574, R_4 = 0.6465$$

$$R_5 = 0.5133, R_6 = 0.6148, R_7 = 0.5187, R_8 = 0.4502$$

Step 6: The ranking order of alternatives can be obtained according to the value of grey relational degree, It is observed that $R_4 > R_6 > R_2 > R_3 > R_7 > R_1 > R_5 > R_8$ and so the highest value of grey relative relational degree is R_4. Therefore R_4 represent the alternative Artificial intelligence, this technology contributes more than other technology in maternal health care.

5. Results and Discussion

Recent advances in technology offer several benefits, including: Examples include improved prenatal monitoring, telemedicine, early diagnosis, early detection of complications, and pain management during labor. These advances will improve access to health care, reduce maternal mortality, and promote better outcomes for mothers and newborns. These results suggest that maternal and child health systems can greatly benefit from artificial intelligence (R_4). AI has the potential to improve maternal health by improving early detection, personalizing care, and optimizing health care delivery. Telemedicine (R_6), IoMT and wearable medical devices (R_2) also offer many benefits to maternal health systems.

6. Conclusion

This study evaluates recent technological advances in maternal health using a proposed multi-criteria decision-making approach. The DEMATEL method and Grey Relational Analysis method (GRA) are integrated in this solving procedure to evaluate the alternatives. This method is suitable to solve decision making problem with more criteria and alternatives. In the future, this MCDM technique will be extended and applied to various extensions of neutrosophic sets.

References

[1] L.A. Zadeh, Fuzzy set, *Information and control*.vol 8 (1965), 338-353

[2] Krassimir, T. A., & Parvathi, R. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, *20*(1), 87-96..

[3] Smarandache, F. (1998). Neutrosophy: neutrosophic probability, set, and logic: analytic synthesis & synthetic analysis.

[4] Smarandache, F. (2006, May). Neutrosophic set-a generalization of the intuitionistic fuzzy set. In *2006 IEEE international conference on granular computing* (pp. 38-42). IEEE.

[5] Julong, D. (1989). Introduction to grey system theory. *The Journal of grey system*, *1*(1), 1-24.

[6] Yager, R. R., & Abbasov, A. M. (2013). Pythagorean membership grades, complex numbers, and decision making. *International journal of intelligent systems*, *28*(5), 436-452.

[7] Zhang, X., & Xu, Z. (2014). Extension of TOPSIS to multiple criteria decision making with Pythagorean fuzzy sets. *International journal of intelligent systems*, *29*(12), 1061-1078.

[8] X. Peng, H. Yuan, and Y. Yang, (2017) Pythagorean fuzzy information measures and their applications, *International Journal of Intelligent systems*, Vol 32, no.12, 991-1029 .

[9] Liu, F., Aiwu, G., Lukovac, V., & Vukic, M. (2018). A multicriteria model for the selection of the transport service provider: A single valued neutrosophic DEMATEL multicriteria model. *Decision Making: Applications in Management and Engineering*, *1*(2), 121-130.

[10] Jansi, R., Mohana, K., & Smarandache, F. (2019). *Correlation measure for Pythagorean neutrosophic sets with T and F as dependent neutrosophic components*. Infinite Study.

[11] Mamites, I., Almerino, P., Sitoy, R., Atibing, N. M., Almerino, J. G., Cebe, D., ... & Ocampo, L. (2022). Factors influencing teaching quality in universities: analyzing causal relationships based on neutrosophic DEMATEL. *Education Research International*, *2022*.

[12] NGUYEN, P. H., TSAI, J. F., NGUYEN, T. T., NGUYEN, T. G., & VU, D. D. (2020). A grey MCDM based on DEMATEL model for real estate evaluation and selection problems: a numerical example. *The Journal of Asian Finance, Economics and Business*, *7*(11), 549-556.

[13] Prema, R., & Radha, R. (2022). Generalized neutrosophic pythagorean set. *International research journal of modernization in engineering technology and science*, *11*, 1571-1575.

[14] Ismail, J. N., Rodzi, Z., Al-Sharqi, F., Hashim, H., & Sulaiman, N. H. (2023). The integrated novel framework: linguistic variables in pythagorean neutrosophic set with DEMATEL for enhanced decision support. *Int. J. Neutrosophic Sci*, *21*(2), 129-141.

[15] Poornima, R. (2023). Neutrosophic Set Based Traffic Mechanism Organization. *Advances in Nonlinear Variational Inequalities*, *26*(4), 01-11.