Generalization of neutrosophic interval-valued soft sets with different aggregating operators using multi-criteria group decision-making

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Abstract

In this paper, we present the Pythagorean neutrosophic interval valued fuzzy soft set. This is a generalization of the Pythagorean interval valued fuzzy soft set as well as the neutrosophic interval valued fuzzy soft set. It is discussed in this paper how an aggregated operation is used to aggregate the decision matrix of PNIVS. There are a number of extensions to the normosophic fuzzy soft sets that involve the use of multi-criteria decision-making. The aim of this study is to develop a score function based on aggregating TOPSIS methods in order to find ideal solutions for PNIVS that have both positive and negative values. The purpose of this study is to identify the optimal alternative under closeness conditions. It gives us the opportunity to interact with two real life problems, such as the production of ten different types of motorbikes by an automobile company. According to this set of parameters, a motorbike is determined by the fuel tank capacity, better styling, a better price, more mileage, durable, and other factors that determine how a customer can choose which bike to buy.

Keywords: PNIVS set; MCGDM; TOPSIS; Aggregation operator

1 Introduction

The decision-making (DM) process should consider both individuals and groups of objectives simultaneously. There are many different issues that are related to MADM that are dealt with on a daily basis. The result of this is that we need to improve our DM abilities as a result. Decision making involves deciding among options what is the most appropriate alternative. Hwang et al.[1] that the use of multiple criteria decision making (MCDM) can be beneficial. MCDM problem expressed as a matrix

$$\mathscr{D}_{m\times n} = \begin{array}{c} \\ \Omega_1 \\ \Omega_2 \\ \vdots \\ \Omega_m \end{array} \begin{array}{c} \begin{array}{cccc} \mathscr{D}_1 & \mathscr{D}_2 & \dots & \mathscr{D}_n \end{array} \\ \begin{pmatrix} \tau_{11} & \tau_{12} & \dots & \tau_{1n} \\ \tau_{21} & \tau_{22} & \dots & \tau_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tau_{m1} & \tau_{m2} & \dots & \tau_{mn} \end{pmatrix} \end{array}$$

where $\Omega_1, \Omega_2, ..., \Omega_m$ are alternatives and $\mathscr{D}_1, \mathscr{D}_2, ..., \mathscr{D}_n$ are criteria and τ_{ij} is the rating of ${}_i$ to $\mathscr{D}_j$. In 2013, A fuzzy soft set area with interval values was investigated by Xiao et al.[2] for MAGDM problems under uncertain

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environments. This field of study has been studied by a variety of researchers using a variety of methods. There are several uncertain theories proposed by them to deal with the uncertainties, including fuzzy set (FS),[3] intuitionistic FS (IFS),[4] interval valued FS (IVFS),[5] vague set,[6] Pythagorean FS (PyFS),[7] IVPFS,[8] spherical FS (SFS).[9] A membership grade (MG) indicates how well a FS fits into the specified set with ranging from 0 to one. An IFS is defined by Atanassov[4] as having a total of membership grade (MG) and non-membership grade (NMG) less than one. The sum of the MG and NMG is sometimes greater than one when a DM method is applied. Yager of[7] developed PFS, which is characterized by a square sum of its MG and NMG is more than one. In order to generalize IFS, Yager used PFS to build a model.

This is insufficient for demonstrating neutrality (neither favor nor disfavor). It was developed by Cuong et al.[10] with a total grade no higher than one for three pointers such as positive, neutral, and negative. As a result, it would be appropriate for the DM method to use this set over IFS or PFS for selective applications.[11] Liu et al. first presented the concept of an aggregation operator (AO) in generalized PFS.[12] A PIVFS algorithm for the problem of identifying truth membership grades (TMGs), indeterminacy membership grades (IMGs) and false membership grades (FMGs) with AOs[8] have the feature that the sum of the three grades (TMG, IMG, and FMG) is greater than one. It has been suggested by Ashraf et al.[9] that the SFS should contain the following graph: this diagram shows that the sum of the squares of the TMG, IMG and FMG should be not exceeds one. An application of Pythagorean fuzzy soft set theory to real life was discussed by Peng et al.[13] in 2015. Recent studies on complex Pythagorean FSs using pattern recognition by Ullah et al.[14] Jana et al.[15] examined bipolar intuitionistic fuzzy soft sets with applications. The area of robust single valued neutrosophic soft AOs based on MCDM with bipolar fuzzy soft structure was introduced by Jana et al.[16] in 2019 in regards to robust single valued neutrosophic soft operators with extension on MCDM.[17] The Pythagorean fuzzy dombi AOs were introduced by Jana et al. in 2019.[18] Using trapezoidal neutrosophic AOs for MADM, Jana et al.[19] extrapolated their results and demonstrated their use in MADM . The MCDM process developed by Jana et al.[20] are developing is based on single value neutrosophic dombi power aggregation operators that are applied to the MCDM process of 2021. The concepts of MCDM based on SVTrN aggregation functions have been introduced by Jana et al.[21] as an approach for MCDMs.

It has been studied by many researchers that the VIKOR method is an effective way to solve DM problems. Boran et al.[22] in 2009, multi-criterion intuitionistic fuzzy group decision-making (GDM) is applied to TOPSIS. The bipolar fuzzy TOPSIS for GDM was proposed by Akram et al.[23] The search results of the proposed m-polar fuzzy linguistic TOPSIS approach for MCGDM were discussed by Adeel et al.[24] after 2019. GDM based on TOPSIS has been discussed by Eraslan et al.[25] PFSs based on TOPSIS were proposed to be extended to MCDM by Zhang et al.[26] With regard to the concept of single-valued neutrosophic MADM, Peng et al.[27] initiated the concept by combining MABAC and TOPSIS in 2018. Zulqarnain et al.[28] discussed the TOPSIS extension to interval valued intuitionistic fuzzy soft sets (IVIFSS), highlighting the possibility of extending TOPSIS. As well as discussing IVIFSS's, a new type of correlation coefficient, he discussed a new type of regression coefficient. Based on the TOPSIS method, distances to a positive ideal solution (PIS) and a negative ideal solution (NIS) are computed under relative closeness, and a preference order is calculated to substitute the two distance measures with each other to find the optimum solution. The VIKOR method focuses on ranking and selecting among a set of alternative solutions for a problem that has inconsistent criteria, and it calculates compromise solutions for a problem that has inconsistent criteria, which will help the decision-makers to reach a final decision.[29] The VIKOR method, based on fuzzy logic, was discussed by Opricovic et al.[30] Using a public transportation problem as an example, Tzeng et al.[31] compared VIKOR with TOPSIS methods in the context of a comparison. Recently, Palanikumar et al.[32–39] discussed many AOs based on Neutrosphic logic, SFSs, soft sets are introduced.

It is argued that the purpose of the paper is to extend MCDM approach which are used to describe Pythagorean neutrosophic interval valued fuzzy soft sets under AO and to derive some of its properties. Accordingly, the paper is divided into four sections, which can be found in the following sections. A brief introduction can be found in section 1. There is a brief description of PyNIVS set in Section 2. Section 3 discusses about MCGDM based on PNIVS set using AO with several examples are provided. There is a conclusion provided in the section 4.

2 Preliminaries

Definition 2.1. The PIVFS $\widehat{X} = \left\{x, \left\langle \widehat{\varrho^{t}_{X}}(x), \widehat{\varrho^{f}_{X}}(x) \right\rangle \middle| x \in \mathbb{U}\right\}$, $\widehat{\varrho^{t}_{X}}(x) = \left[\varrho^{tl}_{X}(x), \varrho^{tu}_{X}(x)\right]$ and $\widehat{\varrho^{f}_{X}}(x) = \left[\varrho^{fl}_{X}(x), \varrho^{fu}_{X}(x)\right]$ denotes the MG and NMG of X respectively. Here $\widehat{\varrho^{t}_{X}}$ and $\widehat{\varrho^{f}_{X}}$ are function from $\mathbb{U}$ into

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$\mathbb{D}[0,1]$ and $0 \leq (\widehat{\varrho^t_X}(x))^2 + (\widehat{\varrho^f_X}(x))^2 \leq 1$ it is observed that $0 \leq (\varrho^{tu}_X(x))^2 + (\varrho^{fu}_X(x))^2 \leq 1$.

Definition 2.2. The neutrosophic set (NS) $X = \Big\{x, \langle \varrho^t_X(x), \varrho^f_X(x)\rangle | x \in \mathbb{U}\Big\}$, where $\varrho^t_X(x)$ and $\varrho^f_X(x)$ are called MG and NMG of X respectively. Here ϱ^t_X and ϱ^f_X are function from $\mathbb{U}$ into $[0,1]$ and $0 \leq (\varrho^t_X(x))^3 + (\varrho^f_X(x))^3 \leq 1$.

Definition 2.3. The neutrosophic interval valued set $\widehat{X} = \Big\{x, \Big(\widehat{\sigma^t_X}(x), \widehat{\sigma^I_X}(x), \widehat{\sigma^f_X}(x)\Big) | x \in \mathbb{U}\Big\}$, where $\widehat{\sigma^t_X}(x) = \Big[\sigma^{tl}_X(x), \sigma^{tu}_X(x)\Big]$, $\widehat{\sigma^I_X}(x) = \Big[\sigma^{Il}_X(x), \sigma^{Iu}_X(x)\Big]$ and $\widehat{\sigma^f_X}(x) = \Big[\sigma^{fl}_X(x), \sigma^{fu}_X(x)\Big]$ represents the MG, indeterminacy degree and NMG of X respectively. Consider the mapping $\widehat{\sigma^t_X}, \widehat{\sigma^I_X}, \widehat{\sigma^f_X} : \mathbb{U} \to D[0,1]$ and $0 \leq (\widehat{\sigma^t_X}(x))^2 + (\widehat{\sigma^I_X}(x))^2 + (\widehat{\sigma^f_X}(x))^2 \leq 2$. Here $\widehat{X} = \Big(\Big[\sigma^{tl}_X, \sigma^{tu}_X\Big], \Big[\sigma^{Il}_X, \sigma^{Iu}_X\Big], \Big[\sigma^{fl}_X, \sigma^{fu}_X\Big]\Big)$ is called a Pythagorean neutrosophic interval valued number (PNIVN).

Definition 2.4. Let E be the set of parameter, the pair $\widehat{(\Delta, X)}$ or $\widehat{\Delta_X}$ is called a PNIVS set on $\mathbb{U}$ if $X \sqsubseteq E$ and $\Delta : X \to PyNIV^{\mathbb{U}}$, $PyNIV^{\mathbb{U}}$ is represent the set of all PNIVF subsets of $\mathbb{U}$. That is

$$\widehat{\Delta_X} = \left\{ \left(e, \left\{ \frac{x}{\left(\left[\sigma^{tl}_{\Delta_X}(x), \sigma^{tu}_{\Delta_X}(x)\right], \left[\sigma^{Il}_{\Delta_X}(x), \sigma^{Iu}_{\Delta_X}(x)\right], \left[\sigma^{fl}_{\Delta_X}(x), \sigma^{fu}_{\Delta_X}(x)\right]\right)} \right\}\right) : e \in X, x \in \mathbb{U} \right\}.$$

Remark 2.5. If we write $\widehat{p_{ij}} = \widehat{\sigma^t_{\Delta_X}}(e_j)(x_i)$, $\widehat{q_{ij}} = \widehat{\sigma^I_{\Delta_X}}(e_j)(x_i)$ and $\widehat{r_{ij}} = \widehat{\sigma^f_{\Delta_X}}(e_j)(x_i)$, where $i = 1, 2, ..., m$ and $j = 1, 2, ..., n$ then the PyNIVS set $\widehat{\Delta_X}$ defined in matrix form:

$$\widehat{\Delta_X} = [(\widehat{p_{ij}}, \widehat{q_{ij}}, \widehat{r_{ij}})]_{m \times n} = \begin{bmatrix} (\widehat{p_{11}}, \widehat{q_{11}}, \widehat{r_{11}}) & (\widehat{p_{12}}, \widehat{q_{12}}, \widehat{r_{12}}) & \cdots & (\widehat{p_{1n}}, \widehat{q_{1n}}, \widehat{r_{1n}}) \\ (\widehat{p_{21}}, \widehat{q_{21}}, \widehat{r_{21}}) & (\widehat{p_{22}}, \widehat{q_{22}}, \widehat{r_{22}}) & \cdots & (\widehat{p_{2n}}, \widehat{q_{2n}}, \widehat{r_{2n}}) \\ \vdots & \vdots & \ddots & \vdots \\ (\widehat{p_{m1}}, \widehat{q_{m1}}, \widehat{r_{m1}}) & (\widehat{p_{m2}}, \widehat{q_{m2}}, \widehat{r_{m2}}) & \cdots & (\widehat{p_{mn}}, \widehat{q_{mn}}, \widehat{r_{mn}}) \end{bmatrix}$$

The matrix is known as Pythagorean neutrosophic interval valued soft matrix (PNIVSM).

3 MCGDM using PNIVS sets

Definition 3.1. The cardinal set of PNIVS set $\widehat{\eth_X}$ is defined as

$$\widehat{c\eth_X} = \left\{ \frac{e}{\left(\left[\tau^{Tl}_{c\theta_X}(e), \tau^{Tu}_{c\theta_X}(e)\right], \left[\tau^{Il}_{c\xi_X}(e), \tau^{Iu}_{c\xi_X}(e)\right], \left[\tau^{Fl}_{c\varphi_X}(e), \tau^{Fu}_{c\varphi_X}(e)\right]\right)} : e \in E \right\}$$

$$= \left\{ \frac{e}{\left(\widehat{\tau^T}_{c\theta_X}(e), \widehat{\tau^I}_{c\xi_X}(e), \widehat{\tau^F}_{c\varphi_X}(e)\right)} : e \in E \right\}$$, The collection of all cardinal sets of PNIVS sets of $\mathbb{U}$ is represented as $cPNIV^{\mathbb{U}}$. If $X \subseteq E = \{e_i : i = 1, 2, ..., n\}$, then $\widehat{c\eth_X} \in cPNIV^{\mathbb{U}}$ may be represented in matrix form as $\Big[\ ([p^l_{1j}, p^u_{1j}], [q^l_{1j}, q^u_{1j}], [r^l_{1j}, r^u_{1j}])\ \Big]_{1 \times n} = \Big[\ ([p^l_{11}, p^u_{11}], [q^l_{11}, q^u_{11}], [r^l_{11}, r^u_{11}])\ , ([p^l_{12}, p^u_{12}], [q^l_{12}, q^u_{12}], [r^l_{12}, r^u_{12}])\ , ..., ([p^l_{1n},$

where $\big([p^l_{1j}, p^u_{1j}], [q^l_{1j}, q^u_{1j}], [r^l_{1j}, r^u_{1j}]\big) = \Big[\mu^l_{c\eth_X}(e_j), \mu^u_{c\eth_X}(e_j)\Big]$. For our convenience, consider matrix form as

$[(\widehat{p}_{1j}, \widehat{q}_{1j}, \widehat{r}_{1j})]_{1 \times n} = [(\widehat{p}_{11}, \widehat{q}_{11}, \widehat{r}_{11}), (\widehat{p}_{12}, \widehat{q}_{12}, \widehat{r}_{12}), ..., (\widehat{p}_{1n}, \widehat{q}_{1n}, \widehat{r}_{1n})]$, where $(\widehat{p}_{1j}, \widehat{q}_{1j}, \widehat{r}_{1j}) = \widehat{\mu}_{c\eth_X}(e_j)$, for $j = 1, 2, ..., n$. Hence this matrix is called a cardinal matrix of $\widehat{c\eth_X}$ of E.

Definition 3.2. Let $\widehat{\eth_X} \in PNIV^{\mathbb{U}}$ and $\widehat{c\eth_X} \in cPNIV^{\mathbb{U}}$. The PNIVS set aggregation operator $PNIVS_{agg} : cPNIV^{\mathbb{U}} \times PNIV^{\mathbb{U}} \to PNIVS(\mathbb{U}, E)$ is defined as

$$PNIVS_{agg}(\widehat{c\eth_X}, \widehat{\eth_X}) = \left\{ \frac{x}{\widehat{\mu}_{\eth^*_X}(x)} : x \in \mathbb{U} \right\} = \left\{ \frac{x}{\left(\widehat{\tau^T}_{\theta^*_X}(x), \widehat{\tau^I}_{\xi^*_X}(x), \widehat{\tau^F}_{\varphi^*_X}(x)\right)} : x \in \mathbb{U} \right\}.$$

This collection is called aggregate PNIVS set $\widehat{\eth_X}$. The MG $\widehat{\tau^T}_{\theta^*_X}(x) : \mathbb{U} \to D[0,1]$ by $\widehat{\tau^T}_{\theta^*_X}(x) = \frac{1}{|E|} \sum_{e \in E} \left(\widehat{\tau^T}_{c\theta_X}(e), \widehat{\tau^T}_{\theta_X}(e)\right)(x)$, IMG $\widehat{\tau^I}_{\xi^*_X}(x) : \mathbb{U} \to D[0,1]$ by $\widehat{\tau^I}_{\xi^*_X}(x) = \frac{1}{|E|} \sum_{e \in E} \left(\widehat{\tau^I}_{c\xi_X}(e), \widehat{\tau^I}_{\xi_X}(e)\right)(x)$

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and NMG $\widehat{\tau^F}_{\varphi_X^*}(x) : \mathbb{U} \to D[0,1]$ by $\widehat{\tau^F}_{\varphi_X^*}(x) = \frac{1}{|E|}\sum_{e\in E}\left(\widehat{\tau^F}_{c\varphi_X}(e), \widehat{\tau^F}_{\varphi_X}(e)\right)(x)$. The set $PNIVS_{agg}(\widehat{c\eth_X}, \widehat{\eth_X})$ is expressed in matrix form as

$$\left[\ \left([p_{i1}^l, p_{i1}^u], [q_{i1}^l, q_{i1}^u], [r_{i1}^l, r_{i1}^u]\right)\ \right]_{m\times 1} = \begin{bmatrix} \left([p_{11}^l, p_{11}^u], [q_{11}^l, q_{11}^u], [r_{11}^l, r_{11}^u]\right) \\ \left([p_{21}^l, p_{21}^u], [q_{21}^l, q_{21}^u], [r_{21}^l, r_{21}^u]\right) \\ \vdots \\ \left([p_{m1}^l, p_{m1}^u], [q_{m1}^l, q_{m1}^u], [r_{m1}^l, r_{m1}^u]\right) \end{bmatrix}$$

where $\left[\ \left([p_{i1}^l, p_{i1}^u], [q_{i1}^l, q_{i1}^u], [r_{i1}^l, r_{i1}^u]\right)\ \right] = \left[\mu^l_{\eth_X^*}(u_i), \mu^u_{\eth_X^*}(u_i)\right]$, for $i = 1, 2, ..., m$ is called PNIVS aggregate matrix of $PNIVS_{agg}(\widehat{c\eth_X}, \widehat{\eth_X})$ over $\mathbb{U}$.

Theorem 3.3. *Let $\widehat{\eth_X}$ be an PNIVS set. Suppose that $\widehat{M_{\eth_X}}, \widehat{M_{c\eth_X}}, \widehat{M^*_{\eth_X}}$ are matrices of $\widehat{\eth_X}, \widehat{c\eth_X}, \widehat{\eth^*_X}$ respectively, then $\widehat{M_{\eth_X}} \circ \widehat{M^{\mathbb{T}}_{c\eth_X}} = \widehat{M^*_{\eth_X}} \times |E|$, where $\widehat{M_{\eth_X}} \circ \widehat{M^{\mathbb{T}}_{c\eth_X}}$ is called a PNIVSM-max min product and $\widehat{M^{\mathbb{T}}_{c\eth_X}}$ is the transpose of $\widehat{M_{c\eth_X}}$.*

Proof. It follows from Definitions 3.1 and Definitions 3.2 that the proof holds.

A MCGDM can be made based on a set of algorithms derived from PNIVS and set by the following methods:

Algorithm-I
Step 1: Input PNIVS set $\widehat{\eth_X}$ over $\mathbb{U}$.
Step 2: Find $\widehat{c\eth_X}$ of $\widehat{\eth_X}$.
Step 3: Obtain aggregate values for PNIVS set $\widehat{\eth^*_X}$ of $\widehat{\eth_X}$.
Step 4: Determine the score value by $S_c(x) = \frac{\left(\tau_x^{2Tl} - \tau_x^{2Iu} - \tau_x^{2Fu}\right) + \left(\tau_x^{2Tu} - \tau_x^{2Il} - \tau_x^{2Fl}\right)}{2}$, $-1 \le S_c(x) \le 1$ and $u \in \mathbb{U}$.
Step 5: This is the maximum output for $S_c(x)$ for the best alternative.

Example 3.4. Assume that there are ten different models of motorbikes made by a company that produces automobiles $\mathbb{U} = \{\Xi_1, \Xi_2, ..., \Xi_{10}\}$. Taking into consideration a set of parameters $E = \{e_1, e_2, ..., e_5\}$, then we should add indices of fuel tank capacity, styling improvement, price improvement, fuel mileage improvement, and durability improvement to describe the aforementioned traits, respectively. It is necessary to make a more informed decision about the type of motorbike that is best suited to the needs of the buyer by evaluating each motorbike in accordance with a set of parameters $X = \{e_1, e_3, e_5\} \subseteq E$ in order to make the right purchase decision.

Step-1: We construct PNIVS set $\widehat{\eth_X}$ of $\mathbb{U}$:

$$\widehat{\eth_X} = \Bigg\{\Bigg(e_1, \Big\{\frac{\Xi_1}{[0.6,0.65], [0.65,0.7], [0.5,0.52]}, \frac{\Xi_2}{[0.65,0.7], [0.5,0.55], [0.6,0.63]}, \frac{\Xi_5}{[0.9,0.95], [0.1,0.13], [0.45,0.5]}, \frac{\Xi_7}{[0.17,0.2], [0.73,0.75], [0.68,0.7]}, \frac{\Xi_{10}}{[0.17,0.25], [0.75,0.8], [0.65,0.68]}\Big\}\Bigg),$$
$$\Bigg(e_3, \Big\{\frac{\Xi_3}{[0.58,0.65], [0.65,0.7], [0.5,0.53]}, \frac{\Xi_4}{[0.2,0.5], [0.75,0.78], [0.65,0.67]}, \frac{\Xi_6}{[0.5,0.55], [0.7,0.8], [0.75,0.78]}, \frac{\Xi_8}{[0.23,0.35], [0.56,0.58], [0.8,0.83]}, \frac{\Xi_9}{[0.6,0.65], [0.65,0.68], [0.48,0.5]}\Big\}\Bigg),$$
$$\Bigg(e_5, \Big\{\frac{\Xi_1}{[0.24,0.3], [0.77,0.78], [0.6,0.62]}, \frac{\Xi_2}{[0.8,0.85], [0.1,0.12], [0.6,0.64]}, \frac{\Xi_3}{[0.32,0.35], [0.7,0.72], [0.65,0.67]}, \frac{\Xi_4}{[0.33,0.4], [0.9,0.95], [0.3,0.35]}, \frac{\Xi_5}{[0.26,0.5], [0.7,0.72], [0.7,0.75]}, \frac{\Xi_8}{[0.85,0.9], [0.15,0.2], [0.6,0.62]}\Big\}\Bigg)\Bigg\}.$$

Step-2: $\widehat{c\eth_X} = \Big\{\frac{e_1}{([0.249,0.275], [0.273,0.293], [0.288,0.303])}, \frac{e_3}{([0.211,0.27], [0.331,0.354], [0.318,0.331])}, \frac{e_5}{([0.28,0.33], [0.332,0.349], [0.345,0.365])}\Big\}$.

Step-3: The aggregate PNIVS set $\widehat{\eth^*_X}$ of $\widehat{\eth_X}$ is $\widehat{M_{\eth^*_X}} = \frac{\widehat{M_{\eth_X}} \circ \widehat{M^{\mathbb{T}}_{c\eth_X}}}{|E|}$

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$$= \frac{1}{5}\left\{\begin{bmatrix} [0.6,0.65] & [0,0] & [0,0] & [0,0] & [0.24,0.3] \\ [0.65,0.7] & [0,0] & [0,0] & [0,0] & [0.8,0.85] \\ [0,0] & [0,0] & [0.58,0.65] & [0,0] & [0.32,0.35] \\ [0,0] & [0,0] & [0.2,0.5] & [0,0] & [0.33,0.4] \\ [0.9,0.95] & [0,0] & [0,0] & [0,0] & [0.26,0.5] \\ [0,0] & [0,0] & [0.5,0.55] & [0,0] & [0,0] \\ [0.17,0.2] & [0,0] & [0,0] & [0,0] & [0,0] \\ [0,0] & [0,0] & [0.23,0.35] & [0,0] & [0.85,0.9] \\ [0,0] & [0,0] & [0.6,0.65] & [0,0] & [0,0] \\ [0.17,0.25] & [0,0] & [0,0] & [0,0] & [0,0] \end{bmatrix}\begin{bmatrix} [0.249,0.275] \\ [0,0] \\ [0.211,0.27] \\ [0,0] \\ [0.28,0.33] \end{bmatrix},\right.$$

$$\begin{bmatrix} [0.65,0.7] & [0,0] & [0,0] & [0,0] & [0.77,0.78] \\ [0.5,0.55] & [0,0] & [0,0] & [0,0] & [0.1,0.12] \\ [0,0] & [0,0] & [0.65,0.7] & [0,0] & [0.7,0.72] \\ [0,0] & [0,0] & [0.75,0.78] & [0,0] & [0.9,0.95] \\ [0.1,0.13] & [0,0] & [0,0] & [0,0] & [0.7,0.72] \\ [0,0] & [0,0] & [0.7,0.8] & [0,0] & [0,0] \\ [0.73,0.75] & [0,0] & [0,0] & [0,0] & [0,0] \\ [0,0] & [0,0] & [0.56,0.58] & [0,0] & [0.15,0.2] \\ [0,0] & [0,0] & [0.65,0.68] & [0,0] & [0,0] \\ [0.75,0.8] & [0,0] & [0,0] & [0,0] & [0,0] \end{bmatrix}\begin{bmatrix} [0.273,0.293] \\ [0,0] \\ [0.331,0.354] \\ [0,0] \\ [0.332,0.349] \end{bmatrix},$$

$$\left.\begin{bmatrix} [0.5,0.52] & [0,0] & [0,0] & [0,0] & [0.6,0.62] \\ [0.6,0.63] & [0,0] & [0,0] & [0,0] & [0.6,0.64] \\ [0,0] & [0,0] & [0.5,0.53] & [0,0] & [0.65,0.67] \\ [0,0] & [0,0] & [0.65,0.67] & [0,0] & [0.3,0.35] \\ [0.45,0.5] & [0,0] & [0,0] & [0,0] & [0.7,0.75] \\ [0,0] & [0,0] & [0.75,0.78] & [0,0] & [0,0] \\ [0.68,0.7] & [0,0] & [0,0] & [0,0] & [0,0] \\ [0,0] & [0,0] & [0.8,0.83] & [0,0] & [0.6,0.62] \\ [0,0] & [0,0] & [0.48,0.5] & [0,0] & [0,0] \\ [0.65,0.68] & [0,0] & [0,0] & [0,0] & [0,0] \end{bmatrix}\begin{bmatrix} [0.288,0.303] \\ [0,0] \\ [0.318,0.331] \\ [0,0] \\ [0.345,0.365] \end{bmatrix}\right\}$$

$$= \left\{\begin{bmatrix} [0.0498,0.06] \\ [0.056,0.066] \\ [0.056,0.066] \\ [0.056,0.066] \\ [0.052,0.066] \\ [0.0422,0.054] \\ [0.034,0.04] \\ [0.056,0.066] \\ [0.0422,0.054] \\ [0.034,0.04] \end{bmatrix}, \begin{bmatrix} [0.0664,0.0698] \\ [0.0546,0.0586] \\ [0.0664,0.0708] \\ [0.0664,0.0708] \\ [0.0664,0.0698] \\ [0.0662,0.0708] \\ [0.0546,0.0586] \\ [0.0662,0.0708] \\ [0.0662,0.0708] \\ [0.0546,0.0586] \end{bmatrix}, \begin{bmatrix} [0.069,0.073] \\ [0.069,0.073] \\ [0.069,0.073] \\ [0.0636,0.07] \\ [0.069,0.073] \\ [0.0636,0.0662] \\ [0.0576,0.0606] \\ [0.069,0.073] \\ [0.0636,0.0662] \\ [0.0576,0.0606] \end{bmatrix}\right.$$

Hence, $\widehat{\eth^*_X} = \Big\{ \frac{\Xi_1}{([0.0498,0.06],[0.0664,0.0698],[0.069,0.073])}, \frac{\Xi_2}{([0.056,0.066],[0.0546,0.0586],[0.069,0.073])}, \frac{\Xi_3}{([0.056,0.066],[0.0664,0.0708],[0.069,0.073])}, \frac{\Xi_4}{([0.056,0.066],[0.0664,0.0708],[0.0636,0.07])}, \frac{\Xi_5}{([0.052,0.066],[0.0664,0.0698],[0.069,0.073])}, \frac{\Xi_6}{([0.0422,0.054],[0.0662,0.0708],[0.0636,0.0662])}, \frac{\Xi_7}{([0.034,0.04],[0.0546,0.0586],[0.0576,0.0606])}, \frac{\Xi_8}{([0.056,0.066],[0.0662,0.0708],[0.069,0.073])}, \frac{\Xi_9}{([0.0422,0.054],[0.0662,0.0708],[0.0636,0.0662])}, \frac{\Xi_{10}}{([0.034,0.04],[0.0546,0.0586],[0.0576,0.0606])} \Big\}$.

Step-4: The values of the score function $S_c(\Xi_i)$ as follows.

Ξ_i	Ξ_1	Ξ_2	Ξ_3	Ξ_4	Ξ_5
$S_c(\Xi_i)$	-0.00665	-0.00451	-0.00601	-0.00544	-0.00616

Ξ_i	Ξ_6	Ξ_7	Ξ_8	Ξ_9	Ξ_{10}
$S_c(\Xi_i)$	-0.00656	-0.00532	-0.006	-0.00656	-0.00487

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Step 5: Here $\max_i S_c(\Xi_i) = -0.00451$.

Algorithm-II
Step-1: On the basis of the parameters, determine the PNIVS input matrix.
Step-2: (Case-I) Find the choice matrix for the MG, IMG and FMG of PNIVS matrix when weights are equal.
(Case-II) Find the choice matrix for the MG, IMG and FMG of PNIVS matrix when weights are unequal.
Step-3: Compute $S_c(x) = \frac{\left(\tau_x^{2Tl} - \tau_x^{2Iu} - \tau_x^{2Fu}\right) + \left(\tau_x^{2Tu} - \tau_x^{2Il} - \tau_x^{2Fl}\right)}{2}$, $-1 \leq S_c(x) \leq 1$.
Step-4: A maximum output is produced when $S_c(x)$ is applied to the best alternative.

Case-I: Let $\widehat{X} = (\widehat{\tau^T}_{ij}, \widehat{\tau^I}_{ij}, \widehat{\tau^F}_{ij}) \in PNIVSM_{m\times n}$. Then choice matrix of PNIVSM X is given by $\widehat{\mathcal{C}(X)} = \left[\left(\frac{\sum_{j=1}^{n}(\widehat{\tau^T}_{ij})^2}{n}, \frac{\sum_{j=1}^{n}(\widehat{\tau^I}_{ij})^2}{n}, \frac{\sum_{j=1}^{n}(\widehat{\tau^F}_{ij})^2}{n}\right)\right]_{m\times 1}$, $\forall i$ when weights are equal. By Example 3.4,

$$\widehat{\mathcal{C}(X)} = \left\{ \begin{bmatrix} [0.0835, 0.1025] \\ [0.2125, 0.2425] \\ [0.0878, 0.109] \\ [0.0298, 0.082] \\ [0.1755, 0.2305] \\ [0.05, 0.0605] \\ [0.0058, 0.008] \\ [0.1551, 0.1865] \\ [0.072, 0.0845] \\ [0.0058, 0.0125] \end{bmatrix}, \begin{bmatrix} [0.2031, 0.2197] \\ [0.052, 0.0634] \\ [0.1825, 0.2017] \\ [0.2745, 0.3022] \\ [0.1, 0.1071] \\ [0.098, 0.128] \\ [0.1066, 0.1125] \\ [0.0672, 0.0753] \\ [0.0845, 0.0925] \\ [0.1125, 0.128] \end{bmatrix}, \begin{bmatrix} [0.122, 0.131] \\ [0.144, 0.1613] \\ [0.1345, 0.146] \\ [0.1025, 0.1143] \\ [0.1385, 0.1625] \\ [0.1125, 0.1217] \\ [0.0925, 0.098] \\ [0.2, 0.2147] \\ [0.0461, 0.05] \\ [0.0845, 0.0925] \end{bmatrix} \right.$$

The values of the score function $S_c(\Xi_i)$ are follows.

Ξ_i	Ξ_1	Ξ_2	Ξ_3	Ξ_4	Ξ_5
$S_c(\Xi_i)$	-0.05203	0.02524	-0.0469	-0.09131	0.00844

Ξ_i	Ξ_6	Ξ_7	Ξ_8	Ξ_9	Ξ_{10}
$S_c(\Xi_i)$	-0.02365	-0.02104	-0.01872	-0.004	-0.02227

Case-II: Let $\widehat{X} = (\widehat{\tau^T}_{ij}, \widehat{\tau^I}_{ij}, \widehat{\tau^F}_{ij}) \in PNIVSM_{m\times n}$. Then weighted choice matrix of PNIVSM X ($\widehat{w_j} > 0$ are weights mean weights are unequal) is $\widehat{\mathcal{C}_w(X)} = \left[\left(\frac{\sum_{j=1}^{n}\widehat{w_j}(\widehat{\tau^T}_{ij})^2}{\sum \widehat{w_j}}, \frac{\sum_{j=1}^{n}\widehat{w_j}(\widehat{\tau^I}_{ij})^2}{\sum \widehat{w_j}}, \frac{\sum_{j=1}^{n}\widehat{w_j}(\widehat{\tau^F}_{ij})^2}{\sum \widehat{w_j}}\right)\right]_{m\times 1}$, $\forall i$.

Weights $(\widehat{w_j}) = \{[0.16, 0.165], [0.14, 0.145], [0.18, 0.19], [0.17, 0.175], [0.15, 0.155]\}$. By Example 3.4,

$$\widehat{\mathcal{C}_w(X)} = \left\{ \begin{bmatrix} [0.0798, 0.1046] \\ [0.1971, 0.241] \\ [0.0915, 0.1241] \\ [0.0284, 0.0904] \\ [0.1684, 0.2346] \\ [0.0542, 0.0718] \\ [0.0056, 0.0083] \\ [0.142, 0.186] \\ [0.0781, 0.1003] \\ [0.0056, 0.0129] \end{bmatrix}, \begin{bmatrix} [0.1886, 0.2189] \\ [0.05, 0.0652] \\ [0.1802, 0.2168] \\ [0.2684, 0.3194] \\ [0.0905, 0.1039] \\ [0.1063, 0.152] \\ [0.1027, 0.116] \\ [0.0721, 0.0876] \\ [0.0916, 0.1098] \\ [0.1084, 0.132] \end{bmatrix}, \begin{bmatrix} [0.1133, 0.1302] \\ [0.1345, 0.1612] \\ [0.1306, 0.1537] \\ [0.1079, 0.1303] \\ [0.1276, 0.1605] \\ [0.122, 0.1445] \\ [0.0891, 0.1011] \\ [0.2039, 0.2381] \\ [0.05, 0.0594] \\ [0.0814, 0.0954] \end{bmatrix} \right.$$

The values of the score function $S_c(\Xi_i)$ as follows.

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Ξ_i	Ξ_1	Ξ_2	Ξ_3	Ξ_4	Ξ_5
$S_c(\Xi_i)$	-0.04799	0.02307	-0.04819	-0.09684	0.01117

Ξ_i	Ξ_6	Ξ_7	Ξ_8	Ξ_9	Ξ_{10}
$S_c(\Xi_i)$	-0.03103	-0.02104	-0.02817	-0.00516	-0.02236

Algorithm-III

Step-1: Input aggregated PNIV weighted averaging (PNIVWA) numbers u_i by $\widehat{\mathcal{C}(X)} = \left(\sum_{j=1}^{n} \widehat{w_j}\widehat{\tau_{ij}^T}, \sum_{j=1}^{n} \widehat{w_j}\widehat{\tau_{ij}^I}, \sum_{j=1}^{n} \widehat{w_j}\widehat{\tau_{ij}}\right)$.

Step-2: Determine the score function $S_c(x) = \frac{\left(\tau_x^{2Tl} - \tau_x^{2Iu} - \tau_x^{2Fu}\right) + \left(\tau_x^{2Tu} - \tau_x^{2Il} - \tau_x^{2Fl}\right)}{2}$.

Step-3: Output for the best alternative by $S_c(x)$ is maximum.

Weights $(\widehat{w_j}) = \{[0.16, 0.165], [0.14, 0.145], [0.18, 0.19], [0.17, 0.175], [0.15, 0.155]\}$.
By Example 3.4,

$$\widehat{\mathcal{C}(X)} = \left\{ \begin{bmatrix} [0.132, 0.1538] \\ [0.224, 0.2473] \\ [0.1524, 0.1778] \\ [0.0855, 0.157] \\ [0.183, 0.2343] \\ [0.09, 0.1045] \\ [0.0272, 0.033] \\ [0.1689, 0.206] \\ [0.108, 0.1235] \\ [0.0272, 0.0413] \end{bmatrix}, \begin{bmatrix} [0.2195, 0.2364] \\ [0.095, 0.1094] \\ [0.222, 0.2446] \\ [0.27, 0.2955] \\ [0.121, 0.1331] \\ [0.126, 0.152] \\ [0.1168, 0.1238] \\ [0.1233, 0.1412] \\ [0.117, 0.1292] \\ [0.12, 0.132] \end{bmatrix}, \begin{bmatrix} [0.17, 0.1819] \\ [0.186, 0.2032] \\ [0.1875, 0.2046] \\ [0.162, 0.1816] \\ [0.177, 0.1988] \\ [0.135, 0.1482] \\ [0.1088, 0.1155] \\ [0.234, 0.2538] \\ [0.0864, 0.095] \\ [0.104, 0.1122] \end{bmatrix} \right.$$

The values of the score function $S_c(\Xi_i)$ are as follows.

Ξ_i	Ξ_1	Ξ_2	Ξ_3	Ξ_4	Ξ_5
$S_c(\Xi_i)$	-0.06249	0.00723	-0.06564	-0.09372	-0.00741

Ξ_i	Ξ_6	Ξ_7	Ξ_8	Ξ_9	Ξ_{10}
$S_c(\Xi_i)$	-0.03007	-0.02615	-0.04167	-0.00998	-0.02639

3.1 Analysis and discussion

Based on the calculations made up until this point, we can draw the conclusion that the conclusion is correct. It can be deduced on the basis of the calculations that if algorithm I, II and III are taken into consideration, it can be deduced that:

$Methods$	$Ranking\ of\ alternatives$	$Optimal$
$Algorithm - I$	$\Xi_1 \leq \Xi_6 = \Xi_9 \leq \Xi_5 \leq \Xi_3 \leq \Xi_8 \leq \Xi_4 \leq \Xi_7 \leq \Xi_{10} \leq \Xi_2$	Ξ_2
$Algorithm - II\ Case - (i)$	$\Xi_4 \leq \Xi_1 \leq \Xi_3 \leq \Xi_6 \leq \Xi_{10} \leq \Xi_7 \leq \Xi_8 \leq \Xi_9 \leq \Xi_5 \leq \Xi_2$	Ξ_2
$Algorithm - II\ Case - (ii)$	$\Xi_4 \leq \Xi_3 \leq \Xi_1 \leq \Xi_6 \leq \Xi_8 \leq \Xi_{10} \leq \Xi_7 \leq \Xi_9 \leq \Xi_5 \leq \Xi_2$	Ξ_2
$Algorithm - III$	$\Xi_4 \leq \Xi_3 \leq C_1 \leq \Xi_8 \leq \Xi_6 \leq \Xi_{10} \leq \Xi_7 \leq \Xi_9 \leq \Xi_5 \leq \Xi_2$	Ξ_2

Based on the observation of the customer, it would be best to purchase the second motorbike if the customer was to purchase one. Lastly, the customer chooses the second motorbike for a number of reasons. Among them are as follows.

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1. According to the study, the motorcycle has the best fuel tank capacity compared to other bikes in its class.
2. Unlike any other motorbike on the market, it has a much better style.
3. Among the remaining motorbikes, it is determined that the price of the motorbike is the best.
4. A higher mileage is assessed as being in line with the customer's expectations as far as mileage is concerned.
5. There is no other motorbike that is stronger and more durable than this one.

4 Conclusion:

Our goal in this work is to propose a new concept of DM under uncertainty by using PNIVS set. MCGDM is an extension of INFS sets and neutrosophic soft sets. In our discussion, we concluded that algorithms-I, II, and III are based on MCGDM under the PNIVS set. A scoring function value was determined by interacting with the PNIVS aggregation operator. Using TOPSIS, alternatives are ranked based on their relative closeness coefficients decreasing or increasing. We have also included a ranking analysis of the alternatives that we have considered, along with our analysis of the ranking.

Conflicts of Interest: The authors declare no conflict of interest.

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