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A neutrosophic theory based security approach for fog and mobile-edge computing

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ABSTRACT

Despite the many services and virtually infinite resources offered by cloud computing such as virtual reality and intelligent building surveillance, it still faces many problems when intervening several smart objects and devices in human's life. These problems are low latency, mobility and location awareness. For solving these problems of cloud computing, the fog and mobile edge computing have been introduced. The fog and mobile edge computing (FMEC) make services and resources close to users via moving from cloud data centers to the edge of the network. The dependability of FMEC depends on supplying centric services to users. The FMEC considered as a perfect paradigm to the above-mentioned purpose due to their ability to implement the ponderous real time applications directly at the network edge via billions of linked mobile devices. The FMEC faces some challenges as in any novel technology. These challenges are security (network security, data security, privacy of usage, data storage security, etc.) and administrative policies concerns. The critical problem which prohibit the development of FMEC is how to address dynamic varying of security services with the requirements of mobile's users. For handling this problem, we sought to provide a method for selecting the proper security service which is a multi-criteria decision making (MCDM) problem. In this research, we provide a neutrosophic PROMETHEE (preference ranking organization method for enrichment evaluation) technique for multi-criteria decision making problems to describe fuzzy information efficiently. For assessing the proposed methodology we applied it to a real case study to select proper security service for FMEC in the presence of fuzzy information.

1. Introduction

A fulminatory expansion in international mobile traffic has been observed due to the increased number of mobile terminals. Cisco recorded that the mobile traffic increased by 74% in 2015, and this percentage will increase by approximately 8 times from 2016 to 2020 [1]. This growth in mobile traffic also increased the demands of mobile network services. These services can't be accommodated by the classical infrastructure of mobile networking due to shortage of energy efficiency. For solving this problem, the FMEC has been provided. The FMEC considered as innovative and sustainable mobile networking framework, since it transfer capabilities (resources and services) of cloud computing to the users of mobile (at the access network). It also enables access directly to the resources and services with ultra-low latency and high bandwidth.

The security of mobile traffic is a critical problem nowadays, due to the great expansion of mobile network. Few researches have focused on real time and dynamic security services for identifying various security needs of FMEC. Different privacy and security issues were introduced by Lee et al. [2] in the context of cloud based internet of things atmosphere. They categorize different security technologies for securing different components of network such as IoT node, FMEC server, and communication among FMEC server. In the context of other technologies such as wireless sensor network, different security challenges of FMEC were discussed by Stojmenovic et al. [3]. The challenges and security needs of mobile-edge computing were introduced in [4].

These researches didn't provide convenient solutions to mitigate all security matters and challenges specially while counting the communication of mobile-edge computing with other technologies. For this reason, we sought to provide an innovative method for selecting optimal security services according to requirements of mobile users in the FMEC atmosphere. The election process of appropriate security service between numerous available security services is performed based on diverse parameters of

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service's quality such as utilization of CPU and processing delay. So, we can say that the selection of optimal security for satisfying the mobile user requirements is a MCDM problems. Since criteria for selecting appropriate security are usually vague and conflict each other, so some researchers began to use fuzzy theory.

For finding the optimum order of the indispensable security services in FMEC, a fuzzy inference system was established [5]. But, it's a defy for decision makers to obtain optimal decision by using fuzzy theory, since there are usually uncertainties in their choices. If the membership degree for an object is determined by two experts are as follows: The membership degree of first expert is 0.5, and the second expert defined it as 0.7. The hesitation of experts between a set of potential values will cause problems in determining convergent degree of membership for the object. To solve hesitation problem of fuzzy, Torra and Narukawa [6] and Torra [7] introduced the hesitant fuzzy set (HFS). A (HFS) is an expansion of a fuzzy set which assigns multiple values among 0 and 1 to the degree of membership for an object.

However, the fuzzy and hesitant fuzzy sets fails to consider indeterminacy and falsity degree which exist usually in reality. For solving fuzzy theory's problems, Atanassov proposed intuitionistic fuzzy theory [8]. It considers the truth and falsity degrees, but it fails to consider indeterminacy. The truth and falsity degrees in intuitionistic fuzzy theory are relying on each other and this does not happen often in reality.

For dealing with the drawbacks of fuzzy and intuitionistic fuzzy sets, Smarandache introduced the neutrosophic sets [9], which is an expansion of classical, fuzzy and intuitionistic fuzzy sets. It take into consideration the truth, indeterminacy and falsity degrees for representing uncertain and inconsistent information. In neutrosophic theory, the truth, indeterminacy and falsity degrees are independent in nature. It able to deal with inconsistent, indeterminate and incomplete information, but fuzzy and intuitionistic fuzzy can only deal with partial or incomplete information.

For transferring the neutrosophic theory from the philosophic field into the mathematical theory, and becoming applicable in engineering applications, Wang et al. [10] introduced single-valued neutrosophic set.

In our research in order to select the proper security service which is a MCDM problem, we used the neutrosophic PROMETHEE technique for describing fuzzy information efficiently. The PROMETHEE technique utilized by Araz and Ozkarahan to estimate suppliers performance [11]. Many researches focus on PROMETHEE technique in fuzzy environment. A fuzzy PROMETHEE method proposed by Chen, et al. [12]., for supplier selection problem. Chai, et al. [13]. improved PROMETHEE technique under intuitionistic fuzzy environments for supplier selection problem.The PROMETHEE method used by some researchers in diverse fields of making decisions. An incorporated approach of Analytic Hierarchy Process (AHP) and PROMETHEE technique employed together for the equipment selection problem by Dagdeviren [14]. For appropriate selection of machine tool in flexible manufacturing cell an integrated approach based on fuzzy AHP and fuzzy PROMETHEE introduced by Taha and Rostam [15]. A PROMETHEE group decision support system method proposed by Behzadian, et al. [16]. which combined with the quality function deployment (QFD) method. A hybrid fuzzy group decision-making method for supplier estimation based on fuzzy AHP and fuzzy PROMETHEE proposed by Hashemian, et al. [17]. An extended PROMETHEE approach proposed by Chen [18], via using a signed distance-based approach under the environment of interval type-2 fuzzy sets. For wind turbine in road mapping process Ghazinoory et al. [19]. introduced PROMETHEE method in fuzzy environment.

The preference function which used in traditional PROMETHEE methods fails to provide a precise preferences of decision makers, and these functions determines according to decision makers preferences. Therefore, the better consideration of decision makers' preferences and opinions, leads to more precise decision making process.

The PROMETHEE method presented in neutrosophic environment by Wang and Liu [20], via using interval neutrosophic set for selecting the best alternative of energy storage. But in our research we are the first to represent PROMETHEE method for selecting appropriate security service of fog and mobile edge computing via using single valued neutrsophic set which is simple and easy to apply.

The rest of research is arranged as follow: Section 2 describes introductory concepts that includes the PROMETHEE method and neutrosophic set. Section 3 describes the proposed method to select optimal security service for FMEC in the presence of ambiguous information. The application of the proposed method is presented in Section 4. The summary and conclusions of this research are presented in Section 5.

2. Preliminaries

The main idea of this section is to review the solution steps of PROMETHEE technique and also, some essential concepts and definitions related to neutrosophic set that will be needed in our proposed method.

2.1. General overview of PROMETHEE technique expansions

The extraction of partial or complete ranking of alternatives is the basic idea of PROMETHEE technique, which depend on positive, negative and net outranking flow. In recent years, various types of PROMETHEE techniques have been presented and applied in diverse circumstances. Brans developed the PROMETHEE I (partial ranking) and the PROMETHEE II (complete ranking) [21]. Then, numerous diverse types of PROMETHEE technique were introduced, such as the PROMETHEE III (ranking based on intervals) and the PROMETHEE IV (continuous case). For handling problems with segmentation constraints the PROMETHEE V method was introduced, and also the PROMETHEE VI was proposed to represent human brain [22]. For group decision-making, the PROMETHEE GDSS was expanded and the visual interactive module GAIA was recognized for graphical representation. The versions of PROMETHEE methods has been applied successfully in different fields, due to its simplicity. The application fields of PROMETHEE family includes environment [23], business and financial management [24], information technology [25], project selection [26]. A literature review on the application areas of the PROMETHEE techniques was proposed by Behzadian et al. [27]. The PROMETHEE techniques are helpful in managing specific MCDM problem, but there are still some drawbacks. These drawbacks originated from the fact that the family of PROMETHEE techniques which listed above are used crisp data as input, and it is not the common case since fuzziness and impreciseness are widespread in our daily life. The fuzzy data which included in decision making problems originates from:

(1) Subjectivity: which occurs due to subjectivity of personal opinions and differs in which alternatives are significant and which are not.
(2) Incomplete information: occurs due to many cases such as: if decision maker being unfamiliar with the problem, decision maker's self-consideration, and observations shortage.
(3) Qualitative information: occurs due to qualitative preferences and observations which are widespread in our daily life and difficult to handle. For example, "fast" for speed, "cheap" for price, etc.
(4) Approximate evaluation: since the values which engaged in the decision making differ over time and space, then the way to obtain them is the approximate evaluation.

The scholars have expanded the PROMETHEE technique into many various forms because the traditional PROMETHEE techniques fails to handle uncertainty and fuzziness. When the estimation values of alternatives over criteria are represented in interval numbers, Le Téno and Mareschal extended the PROMETHEE technique to deal with this situation [28]. For estimating energy exploitation projects, Goumas and Lygerou utilized the developed fuzzy PROMETHEE technique [29]. It also used by Bilsel et al. [30] for measuring the performances of hospital Web sites. Both the extensions of Le Téno & Mareschal and Goumas & Lygerou only take the values of alternatives represented by interval numbers or fuzzy numbers in fuzzy PROMETHEE technique which used by Le Téno & Mareschal and Goumas & Lygerou, but decision maker's preferences and criteria's weights still crisp values.

Geldermann et al. [31] enhanced the PROMETHEE technique towards fuzzy logic for considering not only fuzzy performances, but also fuzzy preferences and fuzzy weights. Their enhanced version of PROMETHEE was utilized by Zhang et al. [23] for ranking the contaminated sites. The Geldernamm et al.'s expansions failed to process heterogeneous and multi-granular data. For overcoming this drawback, Halouani et al. [26] incorporated PROMETHEE technique with a 2-tuple representation model for overcoming the drawbacks of Geldernamm et al. Their integrated PROMETHEE technique provides simpler and enormous applications of the PROMETHEE technique without immolating any of its advantageous. Also, Li and Li [32] introduced a new extended PROMETHEE technique which based on generalized fuzzy numbers. All previous extensional frameworks of PROMETHEE technique which based on various kinds of fuzzy representations can't be used to state the support and exception information together.

Liao and Xu extended the PROMETHEE technique in intuitionistic fuzzy environment for solving MCDM problems [33]. Also, Rani and Divya developed a framework of intuitionistic fuzzy PROMETHEE technique which based on entropy measure for solving MCDM problems [34]. A new expansion of PROMETHEE technique proposed by Krishkumar and Saeid, to solve supplier selection problem [35]. The PROMETHEE technique modeled with interval-valued intuitionistic fuzzy set for multiple criteria decision analysis as presented by Chen [36]. Since intuitionistic fuzzy sets fails to handle situations which have the truth, falsity and hesitation degrees are independent. Also, almost intuitionistic fuzzy PROMETHEE technique neglected the hesitation degree in their calculations for simplifying it.

Considering the benefits of neutrosophic sets in representing confirmation, contradiction and indeterminacy of humans' perception, for making the PROMETHEE technique more applicable in dealing with uncertain, vague, and inconsistent information, it is significant to expand the PROMETHEE technique within the context of neutrosophic set.

2.2. Steps of classical PROMETHEE approach

For handling the situation where incomparability occurs in most pairwise comparisons, the PROMETHEE technique was proposed. It considers the information among criteria and the information within each criterion, both of which are obvious for decision maker. It also considers the deviation among the estimations of two alternatives on a particular criterion. The decision maker allocates a small preference to the alternative for small deviation and even maybe no preference if he deems that this deviation is frivolous.

For providing a complete ranking of a finite set of alternatives from the best to the worst, the PROMETHEE II was proposed and consists the following steps:

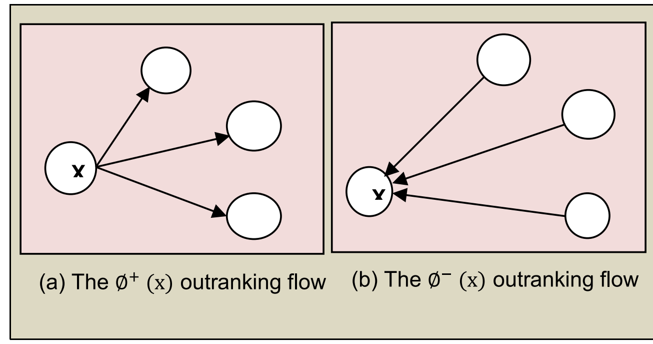


Fig. 1. The outranking flows of PROMETHEE technique.

Step 1: Estimate the alternatives x_i $(i = 1, 2, \ldots, n)$ according to the criteriac_j $(j = 1, 2, \ldots, m)$, and based on pairwise comparisons determine the deviations:

$$dj(x, y) = cj(x) - cj(y) \tag{1}$$

Step 2: Determine the preference among the alternatives x and y through the function:

$$P_j(x, y) = f_j[dj(x, y)], \ \forall x, y \in X, \tag{2}$$

where f_j refers to preference function, which determines the difference among the estimations of the alternatives x and y on the criterion c_j into a preference degree. The preference degree range from 0 to 1, i.e., $0 \le P_j(x,y) \le 1$. The $P_j(x,y)$ starts from 0 if $c_j(x) = c_j(y)$ and still increase to reach 1 if the deviation is large enough. The preference function f_j relates the deviation in performance to preference is called "generalized criterion". Brans and Mareschal presented six kinds of generalized criteria [37], which are: usual criterion, U-shape criterion, V-shape criterion, level criterion, V-shape with indifference criterion, and Gaussian criterion as presented in Table 1.

The decision maker select function's type e according to the nature of problem.

Step 3: Calculate the aggregated preference index

$$\prod(x, y) = \sum_{j=1}^{n} w_j P_j(x, y), \tag{3}$$

where $\mathrm{w_j}$ is the criterion's weight, $0 \le \mathrm{w_j} \le 1$, and $\sum_{j=1}^{\mathrm{n}} \mathrm{w_j} = 1$. The weights can be determined by the decision maker especially when criteria aren't large.

Step 4: Determine positive and negative outranking flow as in Fig. 1:

$$\emptyset^{+}\ (\mathrm{x}) = \frac{1}{n-1} \sum_{\mathrm{z} \in \mathrm{X}} \Pi(\mathrm{x}, \ \mathrm{z}) \tag{4}$$

$$\emptyset^{-}\ (\mathrm{x}) = \frac{1}{n-1} \sum_{\mathrm{z} \in \mathrm{X}} \Pi(\mathrm{z}, \ \mathrm{x}) \tag{5}$$

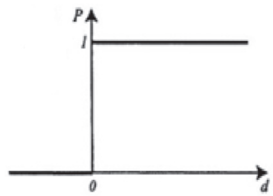
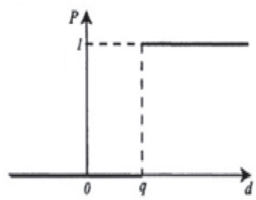
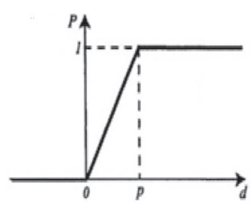
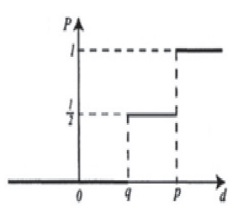
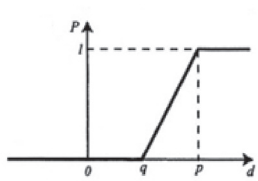
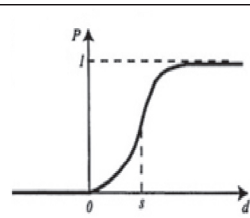
Where $X = (x_1, x_2, \ldots, x_n)^{\mathrm{T}}$ is a set of alternatives. The alternative x outranks alternative y if $\emptyset^{+}(x) \ge \emptyset^{-}(y)$ and $\emptyset^{-}(x) \le \emptyset^{-}(y)$.

Step 5: Calculate the net outranking flow for each alternative to complete final ranking: $\phi(x) = \phi^{+}(x) - \phi^{-}(x)$.

2.3. Neutrosophic set

Neutrosophic set, is an extent of fuzzy and intuitionistic fuzzy set. It was proposed by Smarandache [9] and characterized by a truth membership function T, a falsity membership function F, and

Table 1
Generalized criteria types (preference function: P(d).

Generalized criterion	Definition	Parameter to fix
 Usual criterion	$P(d) = \begin{cases} 0 & d \leq 0 \\ 1 & d > 0 \end{cases}$	-
 U-shape criterion	$P(d) = \begin{cases} 0 & d \leq q \\ 1 & d > q \end{cases}$	q
 V-shape criterion	$P(d) = \begin{cases} 0 & d \leq 0 \\ \frac{d}{p} & 0 \leq d \leq p \\ 1 & d > p \end{cases}$	p
 Level criterion	$P(d) = \begin{cases} 0 & d \leq q \\ \frac{1}{2} & q < d \leq p \\ 1 & d > p \end{cases}$	p, q
 V-shape with indifferent criterion	$P(d) = \begin{cases} 0 & d \leq q \\ \frac{d-q}{p-q} & q < d \leq p \\ 1 & d > p \end{cases}$	p, q
 Gaussian criterion	$P(d) = \begin{cases} 0 & d \leq 0 \\ 1 - e^{-\frac{d^2}{2s^2}} & d > 0 \end{cases}$	S

indeterminacy membership function I. The importance of neutrosophic set returns to its ability to handle inconsistent, indeterminate and incomplete information. The indeterminacy function in neutrsophic set is determined explicitly and truth, falsity membership functions are independent.

For making application of neutrosophic set more easier, the concept of single valued neutrosophic set proposed by Wang et al. [10].

Definition 1. Let ?? be a space of points and ??∈??, then the neutrosophic set A is characterized by a truth-membership function T_A(??), indeterminacy membership function $I_A(x)$ and falsity membership function $F_A(x)$, where T_A(??):??→]$^-$0, 1$^+$[, $I_A(x)$:??→]$^-$0, 1$^+$[and $F_A(x)$:??→]$^-$0, 1$^+$[. There is no restriction on the sum of T_A(??), $I_A(x)$ and $F_A(x)$, so$0^- \leq$ sup T_A(??)+ sup $I_A(x)$+ sup $F_A(x)$ $\leq 3^+$ [38].

Definition 2. A single valued neutrosophic set A over ?? taking the following form A={⟨??,T_A(??), $I_A(x)$, $F_A(x)$⟩:??∈??}, where T_A(??):??→[0,1], I_A(x:??→[0,1] and $F_A(x)$:??→[0,1] with $0 \leq$ T_A(??)+ $I_A(x)$+ $F_A(x)$ ≤ 3 for all ??∈??.

Definition 3. Single valued neutrosophic numbers (SVNN$_s$) have the following operations:

Let $\tilde{B}_1 = (T_1, I_1, F_1)$ and $\tilde{B}_2 = (T_2, I_2, F_2)$ are SVNN$_s$ then,

$$\tilde{B}_1 + \tilde{B}_2 = (T_1 + T_2 - T_1T_2,\ I_1I_2,\ \ F_1F_2),$$

$$\tilde{B}_1 \times \tilde{B}_2 = (T_1T_2,\ \ T_1 + T_2 - T_1T_2,\ I_1I_2,\ \ F_1 + F_2 - F_1F_2).$$

3. Neutrosophic PROMETHEE method

Choosing the best alternative(s) from a set of available candidates with reference to some criteria is widespread in our daily life and named a MCDM problem which has the following mathematical formula:

$$\text{Max/Min } \{c_1(a_i), c_2\ (a_i), \ldots, c_m(a_i)|\ a_i \in A \tag{6}$$

where $A = \{a_1,\ a_2, \ldots,\ a_n\}$ is a set of alternatives, and $c_j(a_i)$ is the estimation value of the alternative a_i over the criterion c_j.

In real life there are some criteria to be maximized and the others to be minimized and the decision maker's objective is to determine an alternative which satisfy all criteria at the same time. But, it is difficult to achieve due to that there barely has an alternative optimizing all criteria simultaneously, particularly when the criteria are conflicting. For example, In energy exploitation projects, the decision maker should take into account not only the economic estimation but also regional development and environmental impact, and the project can't minimize the cost and the environmental impact but meantime maximize the income. Because almost decision making problems which faces us today are MCDM problems, it is extremely significant to develop some suitable methods for finding solution of MCDM problems.

3.1. Neutrosophic weightd of criteria

If the decision maker (DM) is asked to estimate the alternatives over various criteria and then choose the best alternative(s) from them with respect to their estimations values, then the estimations of alternatives over criteria, are performed in analogous to the traditional PROMETHEE decision support system. The significant degrees of the criteria are represented by criteria's weights. According to Geldermann et al. [31]., it is not appropriate for complete decision support system to deem only the fuzzy concept of the preferences. In order to handle this drawback Liao and Xu considered in their framework of PROMETHEE both the intuitionistic fuzzy preferences and intuitionistic fuzzy weights [33]. Since in their calculations of intuitionistic fuzzy weights, they considered only the membership and non-membership degrees and failed to consider indeterminacy degree. So the fuzzy, and intuitionistic fuzzy decision support system are not comprehensive model. Hence, in this research, we develop our enhancement of PROMETHEE with neutrosophic set taking not only neutrosophic preferences but also neutrosophic weights into consideration.

The criteria's weights can be denoted as neutrosophic values $\tilde{\omega}_j$ $(j = 1,\ 2, \ldots,\ m)$, where $T_{\tilde{\omega}_j} \in [0,\ 1]$, $I_{\tilde{\omega}_j} \in [0,\ 1]$, $F_{\tilde{\omega}_j} \in [0,\ 1]$, $T_{\tilde{\omega}_j} + I_{\tilde{\omega}_j} + F_{\tilde{\omega}_j} \leq 3$, $j = 1,\ 2, \ldots,\ m$. $T_{\tilde{\omega}_j}$, $I_{\tilde{\omega}_j}$ and $F_{\tilde{\omega}_j}$ indicate the truth, indeterminacy and falsity membership degrees of the $\tilde{\omega}_j$ respectively.

In the conventional PROMETHEE method, the summation of weights should be ≤ 1. Then, they can't be determined independently and occasionally need normalization. We here calculate the score function of neutrosophic weight and make a normalization process if it required.

Here we don't provide specific methods to determine importance of criteria, but suppose that the DM is appropriate to do so, when the number of the criteria isn't large.

3.2. Generalized criterion

The choice of the generalized criterion which relates the distinction in performances with the preference index, is another way to reflect decision maker's preferences. As we illustrated previously there exist six kinds of generalized criteria, and the most widely used is the linear preference function (V-shape):

$$P(d) = \begin{cases} 0 & d \leq q \\ \frac{d-q}{p-q} & q < d \leq p \\ 1 & d > p \end{cases} \tag{7}$$

The parameters q which is the value of an indifference threshold, and p which is the value of a strict preference threshold should to be specified by the DM according to the problem, and this performs for each criterion. We do not pay much attention to the way for choosing the generalized criterion, since it is the same as classical PROMETHEE. Presume the alternatives values over various criteria are neutrosophic values.

Due to the ability of neutrosophic set in representing vague and uncertain information, then the estimations of criteria represented in neutrsophic values.

In order to calculate the deviations among any two alternatives over each criterion let us do the following:

The score function of neutrosophic values can be written as follows:

Let $\tilde{B} = \langle (T_1,\ I_1,\ F_1) \rangle$ be a single valued neutrosophic number (SVNN) then, the score function $S\ (\tilde{B})$, accuracy function $A(\tilde{B})$ and certainty function $C(\tilde{B})$ of a SVNN are defined as follows:

$$S\left(\tilde{B}\right) = \frac{2 + T_1 - I_1 - F_1}{3} \tag{8}$$

$$A\left(\tilde{B}\right) = T_1 - F_1 \tag{9}$$

$$C\left(\tilde{B}\right) = T_1 \tag{10}$$

$$d_j(x,\ y) = S\left(\tilde{c}_j(x)\right) - S\left(\tilde{c}_j(y)\right), \tag{11}$$

where $\tilde{c}_j(x)$ is a neutrosophic estimation of the alternative x over the criterion c_j, and $S(\tilde{c}_j(x))$ is the score function of $\tilde{c}_j(x)$.

3.3. Building neutrosophic preference relation

In the conventional PROMETHEE method, the decision maker first evaluates the alternatives over diverse criteria using crisp numbers, and then infers the pairwise preferences through the preference function:"generalized criterion". The preferences are constrained within [0,1] in the six kinds of generalized criteria.

If these six types of preference functions defined by using fuzzy set, then we can discover that these six functions can be considered as the membership functions of fuzzy set. The single-valued function "membership function of fuzzy set", can only be utilized to state the strength of "preferred". This contradict usually with reality, since the judgments of decision makers usually exhibit the characteristics of confirmation, contradiction and hesitation in practice. These three characteristics in almost applications are independent in nature, and then the neutrosophic set is the best.

The single-valued function "membership function of fuzzy set", can only be utilized to state the strength of "preferred". This contradict usually with reality, since the judgments of decision makers usually exhibit the characteristics of confirmation, contradiction and hesitation in practice. The three characteristics in almost applications are independent in nature, and then the neutrosophic set is the best.

Due to the ability of neutrosophic set in exemplifying the preferences of a decision maker, we use it here for expressing the decision maker's preferences. The neutrosophic set can express the truth "confirmation" degrees, indeterminate and falsity "negation"" degrees. The neutrosophic preference relation is established by representing all preference values by neutrsophic numbers and storing them in a matrix.

Definition 4. A neutrosophic preference relation R on the set $X = \{x_1, x_2, \ldots, x_n\}$ is represented by a matrix $R = (r_{ik})n \times n$, where $r_{ik} = <(T_{ik}\ I_{ik}, F_{ik})>$, for *all* $i,\ k = 1, 2, \ldots, n$, where T_{ik} indicates the degree to which the object x_i is preferred to the object x_k, F_{ik} denotes the degree to which the object x_i isn't preferred to the object x_k, and I_{ik} is the indeterminacy degree with the condition:

$$T_{ik},\ I_{ik},\ F_{ik} \in [0,\ 1],\ 0 \le T_{ik} + I_{ik} + F_{ik} \le 3,\ T_{ik} = F_{ki},\ T_{ki} = F_{ik},\ I_{ik} \text{ determines according decision maker opinion. For all } i,\ k = 1,\ 2, \ldots, n \tag{12}$$

Now, there exist two approach for constructing the neutrosophic preference relation:

(1) The neutrosophic set consists of three parts: the membership degree and the non-membership degree and indeterminacy degree. We can obtain the membership degree as the similar way of PROMETHEE technique via constructing the performance values and then calculating the preferences through the preference functions:

$$(T_{ik})^j = \begin{cases} 0 & d \le q \\ \frac{d-q}{p-q} & q < d \le p \\ 1 & d > p \end{cases} \tag{13}$$

Therefore we can construct the preference matrix $(E)^j$ as follows:

$$(E)^j = (T_{ik})^j{}_{n \times n} = \begin{bmatrix} - & (T_{12})^j \ldots & (T_{1n})^j \\ (T_{21})^j & - \ldots & (T_{2n})^j \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ (T_{n1})^j & (T_{n2})^j & - \end{bmatrix} \tag{14}$$

But the non-membership degree can be derived by Eq. (12), i.e., $T_{ij} = F_{ji},\ T_{ji} = F_{ij}$.

In order to calculate the indeterminacy degree use the following equation:

$$(I_{ik})^j = \begin{cases} 1 & d \le q \\ \frac{(p-d+I_d(d-q))}{p-q} & q < d \le p \\ I_d & d > p \end{cases} \tag{15}$$

Where I_d is the indeterminacy degree of deviation according to decision maker opinion and depends on his/her understanding of problem.

(2) The second way for constructing the neutrosophic preference relation is via decision maker and without any calculation (i.e. according to decision maker's opinion). But if we let decision maker to construct neutrosophic preference relation, he/she must determine the scale of his/her system and fix it. The authors in [39] presented a method for constructing a consistent neutrsophic preference relation.

3.4. Procedure for NEUTROSOPHIC-PROMETHEE (N-PROMETHEE)

If decision maker evaluated alternatives according to criteria via using crisp values, then the preferences T_{ik} among the alternatives $x_i$and x_k, $(i,\ k = 1,\ 2,\ \ldots,\ n)$ over the criterion c_j can be determined by using Eqs. (2) and (13), and then the preference matrix is as in Eq. (14).

By using Eqs. (12) and (15) we can derive the falsity (non-preference) and indeterminacy degrees. After then we can construct the neutrosophic preference relation over the criterion c_j as follows:

$$\tilde{R}^j = \left(\breve{r}_{ik}{}^j\right) n \times n = \begin{bmatrix} - & \left(T_{12}{}^j, I_{12}{}^j, F_{12}{}^j\right) \ \ldots & \left(T_{1n}{}^j, I_{1n}{}^j, F_{1n}{}^j\right) \\ \left(T_{21}{}^j, I_{21}{}^j, F_{21}{}^j\right) & - \ \ldots & \left(T_{2n}{}^j, I_{2n}{}^j, F_{2n}{}^j\right) \\ \vdots & \vdots & \vdots \\ \left(T_{n1}{}^j, I_{n1}{}^j, F_{n1}{}^j\right) & \left(T_{n2}{}^j, I_{n2}{}^j, F_{n2}{}^j\right) \ldots & - \end{bmatrix} \tag{16}$$

After then, construct the overall neutrosophic preference relation

$$\tilde{R} = \left(\breve{r}_{ik}\right)_{n \times n} = (T_{ik},\ I_{ik}, F_{ik}) = \left(\sum_{j=1}^{m} w_j T_{ik}^j, \sum_{j=1}^{m} w_j I_{ik}^j, \sum_{j=1}^{m} w_j F_{ik}^j\right) \tag{17}$$

Thus, an overall neutrosophic preference relation can be established as follows:

$$\tilde{R} = \left(\breve{r}_{ik}\right) n \times n = \begin{bmatrix} - & (T_{12}, I_{12}, F_{12}) \ \ldots & (T_{1n}, I_{1n}, F_{1n}) \\ (T_{21}, I_{21}, F_{21}) & - \ \ldots & (T_{2n}, I_{2n}, F_{2n}) \\ \vdots & \vdots & \vdots \\ (T_{n1}, I_{n1}, F_{n1}) & (T_{n2}, I_{n2}, F_{n2}) \ldots & - \end{bmatrix}$$

Then, we must calculate the neutrosophic positive outranking flow and the neutrosophic negative outranking as follows:

The neutrosophic positive outranking flow:

$$\tilde{\phi}^+(x_i) = \frac{1}{n-1} * \sum_{k=1,\ i \ne k}^{n} r_{ik} \tag{18}$$

The neutrosophic negative outranking flow:

$$\tilde{\phi}^-(x_i) = \frac{1}{n-1} * \sum_{k=1,\ i \ne k}^{n} r_{ki} \tag{19}$$

Since $\tilde{\phi}^{+}(x_i)$ and $\tilde{\phi}^{-}(x_i)$ are neutrosophic numbers, they can be ranked by the following:

Suppose that $\tilde{B}_1 = \langle(T_1, I_1, F_1)\rangle$ and $\tilde{B}_2 = \langle(T_2, I_2, F_2)\rangle$ are two SVNNs, then the ranking method is defined as follows:

If $S(\tilde{B}_1) > S(\tilde{B}_2)$, then $\tilde{B}_1$ is greater than $\tilde{B}_2$, that is, $\tilde{B}_1$ is superior to $\tilde{B}_2$, denoted by $\tilde{B}_1 > \tilde{B}_2$, where S is the score function which presented in Eq. (8).

Also, If $S(\tilde{B}_1) = S(\tilde{B}_2)$ and $A(\tilde{B}_1) > A(\tilde{B}_2)$, then $\tilde{B}_1$ is greater than $\tilde{B}_2$, that is, $\tilde{B}_1$ is superior to $\tilde{B}_2$, denoted by $\tilde{B}_1 > \tilde{B}_2$.

If $S(\tilde{B}_1) = S(\tilde{B}_2)$, $A(\tilde{B}_1) = A(\tilde{B}_2)$, and $C(\tilde{B}_1) > C(\tilde{B}_2)$, then $\tilde{B}_1$ is greater than $\tilde{B}_2$, that is, $\tilde{B}_1$ is superior to $\tilde{B}_2$, denoted by $\tilde{B}_1 > \tilde{B}_2$.

If $S(\tilde{B}_1) = S(\tilde{B}_2)$, $A(\tilde{B}_1) = A(\tilde{B}_2)$, and $C(\tilde{B}_1) = C(\tilde{B}_2)$, then $\tilde{B}_1$ is indifferent to $\tilde{B}_2$, and denoted by $\tilde{B}_1 = \tilde{B}_2$.

Since the neutrosophic doesn't have subtraction operation, then we can derive the net outranking flow as follows:

$$\phi(x_i) = S\tilde{\phi}^{+}(x_i)) - S\big(\tilde{\phi}^{-}(x_i)\big) \tag{20}$$

When we only consider $\tilde{\phi}^{+}(x_i)$ and $\tilde{\phi}^{-}(x_i)$, then there exist three types of ranking results:

(1) If x_i outranks x_k: $\tilde{\phi}^{+}(x_i) \geq \tilde{\phi}^{+}(x_k)$ and $\tilde{\phi}^{-}(x_i) \leq \tilde{\phi}^{-}(x_k)$ then a partial ranking exist.
(2) The equality ranking exist if: $\tilde{\phi}^{+}(x_i) = \tilde{\phi}^{+}(x_k)$ and $\tilde{\phi}^{-}(x_i) = \tilde{\phi}^{-}(x_k)$.
(3) The incomparability ranking: if $\tilde{\phi}^{+}(x_i) > \tilde{\phi}^{+}(x_k)$ and $\tilde{\phi}^{-}(x_i) > \tilde{\phi}^{-}(x_k)$ or $\tilde{\phi}^{+}(x_i) < \tilde{\phi}^{+}(x_k)$ and $\tilde{\phi}^{-}(x_i) < \tilde{\phi}^{-}(x_k)$. If this situation occur then we can use the score of neutrosophic net outranking for obtaining the complete ranking of all alternatives.

The steps of the NEUTROSOPHIC-PROMETHEE technique for MCDM can be summarized as follows:

ALGORITHM

Step 1: For a decision making problem generate a set of alternatives, $X = \{x_1, x_2, \ldots, x_n\}$, and identify available criteria $C = \{c_1, c_2, \ldots, c_m\}$.

Step 2: Let decision maker evaluate the alternatives according to criteria by using neutrosophic values. Also the relative importance degrees of the criteria $\tilde{w}_j$ $(j = 1, 2, \ldots, m)$ should be determined using neutrosophic numbers, where $T_{\tilde{w}_j} \in [0, 1]$, $I_{\tilde{w}_j} \in [0, 1]$, $F_{\tilde{w}_j} \in [0, 1]$, $T_{\tilde{w}_j} + I_{\tilde{w}_j} + F_{\tilde{w}_j} \leq 3$, $j = 1, 2, \cdots, m$. If you have more than decision maker in your system you must aggregate their opinions as follows:

The aggregation operator (G) is a mapping function denoted as G: $\psi^{n} \to \psi$ such that,

$$G = \begin{cases} \text{Scheme 1, if all decision makers preferences are similar,} \\ \text{Scheme 2, if all decision makers preferences are different partially,} \\ \text{Scheme 3, if all decision makers preferences are totally different.} \end{cases}$$

In case of Scheme 1, use any of the similar values as the aggregated value of decision makers, in case of Scheme 2, the value with the maximum number of occurrence is the aggregated value, and finally incase of Scheme 3, select a moderate value of given preferences and consider it as the aggregated value.

Example. If you have three decision makers D_1, D_2, D_3, and evaluating an alternative A with respect to criterion C. If their evaluation values are $D_1 =$ Extremly Good, $D_2 =$ Good, and $D_3 =$ Extremly Good. The aggregated value of alternative follows Scheme 2, and then the result is $G =$ Extremly Good. If decision makers preferences follows Scheme 1 as follows: $D_1 =$ Good, $D_2 =$ Good, and $D_3 =$ Good. The aggregated value $G =$ Good. If decision makers preferences follows Scheme 3 as follows: $D_1 =$ Extremly Good, $D_2 =$ Good, and $D_3 =$ Medium. Since the maximum preference is Extremly Good, and the moderate term of that zone with other preferences is $G =$ Moderately Good.

Step 3: For each pair of alternatives over various criteria c_j $(j = 1, 2, \ldots, m)$ calculate the deviation through using Eq. (11). Determine the preference function of decision maker, (i.e. establishing the parameters q as an indifference threshold and p as a strict preference threshold). Then use Eqs. (13) and (14) for constructing the preference matrix $E^j (j = 1, 2, \ldots, m)$.

Step 4: Construct the neutrosophic preference relation $\tilde{R}^j = (\breve{r}_{ik}^{\,j})n \times n$ over the criteria c_j $(j = 1, 2, \ldots, m)$.

Step 5: Construct the general neutrosophic preference relation $\tilde{R} = (\breve{r}_{ik})_{n\times n}$ through Eq. (17).

Step 6: Determine the neutrosophic positive outranking flow $\tilde{\phi}^{+}(x_i)$ and the neutrosophic negative outranking flow $\tilde{\phi}^{-}(x_i)$ for the alternative x_i by using Eqs. (18) and (19), respectively.

Step 7: If we compare the $\tilde{\phi}^{+}(x_i)$ and $\tilde{\phi}^{-}(x_i)$ of the alternatives, then it's a partial ranking; Otherwise, a complete ranking will be obtained with respect to the deviation among the score values of the neutrosophic positive outranking flow and that of the neutrosophic negative outranking flow.

Step 8: Make the final ranking and end process.

The general framework of proposed method presented in Fig. 2.

4. Case study and disscusion

For testing the applicability of the suggested framework, we apply it to the popular problem of FMEC security services.

Various security services with overlapping functions exists in FMEC, and offered for the combined security service. Therefore, this entails some basic criteria for differentiating the user satisfaction level and efficiency which presented by every security service on a certain quality of service (QoS) parameter. In the QoS parameter, there exist several prosperities and influential factors of services. These factors include processing delay, CPU usage, overhead and etc. For selecting optimum services from numerous obtainable security services, a MCDM process is required.

By taking into account the most widespread security services in FMEC, we select that as an example:

- Firewall (x_1),
- Network address translator (x_2),
- Deep packet inspection (x_3),
- Load balancer (x_4) and,
- Virtual private network (x_5)

Then, the security service set denoted as $X = \{x_1, x_2, x_3, x_4, x_5\}$. In this set, each service is distinguished by three kinds of parameters:

- Processing delay (c_1),
- CPU usage (c_2) and,
- Memory overhead (c_3).

The implementation steps are given below:

Step 1: In our case study we have three decision makers (D_1, D_2, D_3) to evaluate five alternatives $(x_1, x_2, x_3, x_4, x_5)$ based on three criteria (c_1, c_2, c_3).

Step 2: The relative significant values for alternatives are established by decision makers via using linguistic preferences according to their opinions. These values presented in Tables 2-5.

After then, aggregate weights of alternatives and decision matrix of three decision makers as we illustrated with detail in ***ALGORITHM*** part, especially in step 2 for constructing final matrix of three decision makers matrices. Table 5, shows the aggregated values.

Table 2
The linguistic values and its corresponding neutrsophic values for evaluation process.

Decision matrix's linguistic rating	Corresponding neutrosophic values (NV_S)	Alternatives linguistic rating	Corresponding neutrosophic values (NV_S)
Extremely good (R_3)	(1.0,0.0,0.0)	Highly preferred (R_3)	(1,0.1,0.10)
Moderately good (R_2)	(0.8,0.1,0.1)	Moderately preferred (R_2)	(0.90,0.1,0.25)
Good (R_1)	(0.6,0.2,0.4)	Preferred (R_1)	(0.75,0.2,0.25)
Medium (R_0)	(0.4,0.3,0.6)	Indifferent preferred (R_0)	(0.50,0.50,0.50)
Bad (R_{-1})	(0.3,0.4,0.7)	Less preferred (R_{-1})	(0.35,0.60,0.70)
Moderately Bad (R_{-2})	(0.2,0.5,0.8)	Highly less preferred (R_{-2})	(0.10,0.8,0.90)
Extremely bad (R_{-3})	(0.0,0.1,1.0.)		

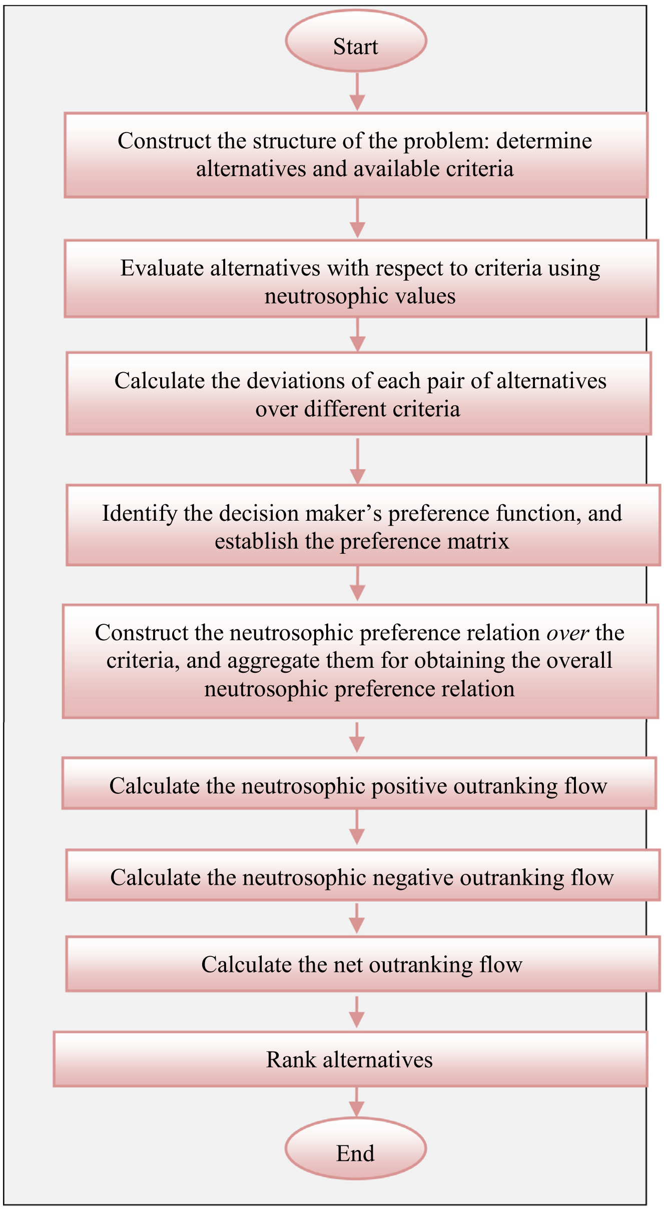


Fig. 2. The general framework of the neutrosophic PROMETHEE.

Table 3
Alternatives weights according to decision makers.

Decision makers	x_1	x_2	x_3	x_4	x_5
D_1	R_0	R_0	R_1	R_2	R_3
D_2	R_{-1}	R_0	R_1	R_1	R_2
D_3	R_{-1}	R_1	R_2	R_2	R_3

Table 4
Decision matrix for security service selection.

Decision makers	Alternatives	Criteria		
		c_1	c_2	c_3
D_1	x_1	R_1	R_0	R_1
	x_2	R_0	R_{-1}	R_0
	x_3	R_2	R_2	R_1
	x_4	R_1	R_1	R_2
	x_5	R_{-1}	R_1	R_{-1}
D_2	x_1	R_0	R_{-1}	R_1
	x_2	R_1	R_0	R_1
	x_3	R_1	R_2	R_0
	x_4	R_2	R_1	R_2
	x_5	R_1	R_0	R_2
D_3	x_1	R_2	R_2	R_1
	x_2	R_0	R_1	R_{-1}
	x_3	R_2	R_{-1}	R_1
	x_4	R_1	R_1	R_0
	x_5	R_1	R_0	R_0

Table 5
Decision matrix for security service selection.

Aggregated values	Weights	c_1	c_2	c_3
x_1	R_{-1}	R_1	R_2	R_1
x_2	R_0	R_1	R_0	R_0
x_3	R_1	R_2	R_2	R_1
x_4	R_2	R_1	R_1	R_2
x_5	R_3	R_1	R_0	R_0

Step 3: Apply the suggested algorithm of NEUTROSOPHIC-PROMETHEE technique, as illustrated previously with details.

Step 3.1: For each pair of alternatives over various criteria c_j ($j = 1, 2, \ldots, m$) calculate the deviation through using Eq. (11). Determine the preference function of decision maker,(i.e. establishing the parameters q as an indifference threshold and p as a strict preference threshold). Then use Eqs. (13) and (14) for constructing the preference matrix $E^j (j = 1, 2, \ldots, m)$.

Firstly, the values of indifference thresholds(q) for all criteria equal to zero, and the strict preference threshold values p as follows: $p = 8\%$ for c_1, $p = 5\%$ for c_2, and $p = 256$ for c_3, which are the minimum values of threshold. The values of p and q determined by decision makers.

To illustrate how we calculates the deviation values for each pair of alternatives over various criteria, let us illustrate example:

The deviation between alternative x_1 and x_2 over c_1 denoted as: $d_1(x_1, x_2) = S(\tilde{c}_1(x_1)) - S(\tilde{c}_1(x_2))$, where $\tilde{c}_1(x_1)$ is a neutrosophic estimation of the alternative x_1 over the criterion c_1, and $S(\tilde{c}_1(x_1))$ is the score function of $\tilde{c}_1(x_1)$. According to Table 5, the neutrosophic estimation value of the alternative x_1 over the criterion c_1 is R_1 which equals (0.6,0.2,0.4) as presented in Table 2. By using Eq. (8), then the S((0.6,0.2,0.4)) = 0.66, and the same thing implement on x_2. The score value of x_2 over c_1 also equal 0.66, then $d_1(x_1, x_2) = 0.66 - 0.66 = 0$.

After then, use Eqs. (13) and (14) for constructing the preference matrix E^1: The value $(T_{12})^1 = 0$, because $d \le q$.

The Final form of preference matrix E^1 is as follows:

$$(E)^1 = (T_{ik})^1{}_{n \times n} = \begin{bmatrix} - & 0 & 0 & 0 & 0 \\ 0 & - & 0 & 0 & 0 \\ 1 & 0 & - & 1 & 1 \\ 0 & 0 & 0 & - & 0 \\ 0 & 0 & 0 & 0 & - \end{bmatrix} \text{and also,}$$

$$(E)^2 = (T_{ik})^2{}_{n \times n} = \begin{bmatrix} - & 1 & 0 & 1 & 1 \\ 0 & - & 0 & 0 & 0 \\ 0 & 1 & - & 1 & 1 \\ 0 & 1 & 0 & - & 1 \\ 0 & 0 & 0 & 0 & - \end{bmatrix}$$

$$(E)^3 = (T_{ik})^3{}_{n \times n} = \begin{bmatrix} - & 0.001 & 0 & 0 & 0.001 \\ 0 & - & 0 & 0 & 0 \\ 0 & 0.001 & - & 0 & 0.001 \\ 0.001 & 0.001 & 0 & - & 0.001 \\ 0 & 0 & 0 & 0 & - \end{bmatrix}$$

Step 3.2: After calculating the preference relation T_{ik} of alternatives, then use Eqs. (12) and (15) to derive the falsity (non-preference) and indeterminacy degrees. After then, construct the neutrosophic preference relation over the criterion c_j as follows:

$$\tilde{R}^j = \left(\check{r}_{ik}{}^j\right) n \times n$$
$$= \begin{bmatrix} - & \left(T_{12}{}^j, I_{12}{}^j, F_{12}{}^j\right) & \dots & \left(T_{1n}{}^j, I_{1n}{}^j, F_{1n}{}^j\right) \\ \left(T_{21}{}^j, I_{21}{}^j, F_{21}{}^j\right) & - & \dots & \left(T_{2n}{}^j, I_{2n}{}^j, F_{2n}{}^j\right) \\ \vdots & \vdots & & \vdots \\ \left(T_{n1}{}^j, I_{n1}{}^j, F_{n1}{}^j\right) & \left(T_{n2}{}^j, I_{n2}{}^j, F_{n2}{}^j\right) & \dots & - \end{bmatrix}$$

Then,

$$\tilde{R}^1 = \left(\check{r}_{ik}{}^1\right) n \times n$$
$$= \begin{bmatrix} - & (0,\ 1,\ 0) & (0,\ 1,\ 1) & (0,\ 1,\ 0) & (0,\ 1,\ 0) \\ (0,\ 1,\ 0) & - & (0,\ 1,\ 1) & (0,\ 1,\ 0) & (0,\ 1,\ 0) \\ (1,\ 0.1,\ 0) & (1,\ 0.1,\ 0) & - & (1,\ 0.1,\ 0) & (1,\ 0.1,\ 0) \\ (0,\ 1,\ 0) & (0,\ 1,\ 0) & (0,\ 1,\ 1) & - & (0,\ 1,\ 0) \\ (0,\ 1,\ 0) & (0,\ 1,\ 0) & (0,\ 1,\ 1) & (0,\ 1,\ 0) & - \end{bmatrix},$$

$$\tilde{R}^2 = \left(\check{r}_{ik}{}^2\right) n \times n$$
$$= \begin{bmatrix} - & (1,\ 0.1, 0) & (0,\ 1, 0) & (1, 0.1, 0) & (1,\ 0.1, 0) \\ (0,\ 1, 1) & - & (0,\ 1, 1) & (0,\ 1, 1) & (0,\ 1, 0) \\ (0,\ 1, 0) & (1,\ 0.1, 0) & - & (1,\ 0.1, 0) & (1,\ 0.1, 0) \\ (0,\ 1, 1) & (1,\ 0.2, 0) & (0, 1, 1) & - & (1, 0.2, 0) \\ (0,\ 1, 1) & (0,\ 1, 0) & (0,\ 1, 1) & (0,\ 1, 1) & - \end{bmatrix},$$

$$\tilde{R}^3 = \left(\check{r}_{ik}{}^3\right) n \times n$$
$$= \begin{bmatrix} - & (0.001,\ 1,\ 0) & (0,\ 1, 0) & (0,\ 1, 0.001) & (0.001,\ 1, 0) \\ (0,\ 1, 0.001) & - & (0,\ 1, 0.001) & (0,\ 1, 0.001) & (0, 1, 0) \\ (0,\ 1, 0) & (0.001,\ 1, 0) & - & (0,\ 1, 0) & (0.001,\ 1, 0) \\ (0.001,\ 0.9, 0) & (0.001,\ 1, 0) & (0,\ 0.9, 0) & - & (0.001,\ 1, 0) \\ (0,\ 1, 0.001) & (0,\ 1, 0) & (0,\ 1, 0.001) & (0,\ 1, 0.001) & - \end{bmatrix},$$

Note that in each pair of alternatives $(x_5,\ x_1)$, $(x_5,\ x_2)$, $(x_5,\ x_3)$, $(x_5,\ x_4)$ for calculating indeterminacy degree, the decision maker proposed indeterminacy of deviation value = 0.1.

Step 3.3: Calculate the general neutrosophic preference relation $\tilde{R} = (\breve{r}_{ik})_{n \times n}$ through Eq. (17):

For reflecting the subjective character, it is not suitable to represent the weights of criteria in crisp values but in neutrosophic values NVs. So the relative importance degrees of the criteria $\tilde{w}_j$ $(j\ = 1,\ 2, \dots,\ m)$ determined by decision makers via using neutrosophic numbers, where $T_{\tilde{w}_j} \in [0,\ 1]$, $I_{\tilde{w}_j} \in [0,\ 1]$, $F_{\tilde{w}_j} \in [0,\ 1]$, $T_{\tilde{w}_j} + I_{\tilde{w}_j} + F_{\tilde{w}_j} \le 3,\ j\ =\ 1,\ 2, \dots, m$.

These weights values are as follows:

$\tilde{w}_1 = (0.9, 0.1, 0.1)$,
$\tilde{w}_2 = (0.6, 0.3, 0.4)$,
$\tilde{w}_3 = (0.8, 0.2, 0.2)$, and by using Eq. (8) to obtain crisp values of weights then,
$w_1 = 0.9,\ w_2 = 0.6,\ w_1 = 0.8$. Since $w_1 + w_1 + w_1$ should be ≤ 1, then a normalization process should apply.

So the final values of criteria's weights are as follows:

$w_1 = 0.39,\ w_2 = 0.26,\ w_3 = 0.34$.

For obtaining general neutrosophic preference relation $\tilde{R} = (\breve{r}_{ik})_{n \times n}$, we use Eq. (17) and the crisp values of criteria weights then,

$$\tilde{R} = \left(\breve{r}_{ik}\right) n \times n$$
$$= \begin{bmatrix} - & (0.3, 0.8,\ 0) & (0,\ 1, 0.4) & (0.3, 0.8, 0) & (0.3, 0.8, 0) \\ (0,\ 1, 0.3) & - & (0,\ 1, 0.6) & (0,\ 0.6, 0.6) & (0,\ 0.8, 0) \\ (0.4, 0.6,\ 0) & (0.6,\ 0.4, 0) & - & (0.6, 0.4, 0) & (0.6, 0.4, 0) \\ (0, 0.9, 0.3) & (0.3, 0.8, 0) & (0, 0.9, 0.6) & - & (0.3,\ 0.8, 0) \\ (0,\ 1, 0.3) & (0,\ 1, 0) & (0,\ 1, 0.6) & (0,\ 1, 0.3) & - \end{bmatrix}$$

Step 3.4: Determine the neutrosophic positive outranking flow $\tilde{\phi}^+(x_i)$ and the neutrosophic negative outranking flow $\tilde{\phi}^-(x_i)$ for the alternative x_i by using Eqs. (18) and (19), respectively:

$$\tilde{\phi}^+(x_1) = (0.12, 0.13, 0.00) \quad \tilde{\phi}^+(x_2) = (0.00, 0.12, 0.00)$$
$$\tilde{\phi}^+(x_3) = (0.24, 0.01, 0.00) \quad \tilde{\phi}^+(x_4) = (0.13, 0.13, 0.00)$$
$$\tilde{\phi}^+(x_5) = (0.00,\ 0.25, 0.00).$$

And

$$\tilde{\phi}^-(x_1) = (0.10, 0.13, 0.00) \quad \tilde{\phi}^-(x_2) = (0.20, 0.06, 0.00)$$

$$\tilde{\phi}^-(x_3) = (0.00, 0.22, 0.02) \quad \tilde{\phi}^-(x_4) = (0.18, 0.05, 0.00)$$

$$\tilde{\phi}^-(x_5) = (0.20, 0.05, 0.00).$$

Step 3.5: Compare the $\tilde{\phi}^+(x_i)$ and $\tilde{\phi}^-(x_i)$ of the alternatives:

$$S\left(\tilde{\phi}^+(x_1)\right) = 0.66,\ S\left(\tilde{\phi}^+(x_2)\right) = 0.63,$$
$$S\left(\tilde{\phi}^+(x_3)\right) = 0.74,\ S\left(\tilde{\phi}^+(x_4)\right) = 0.67,$$
$$S\left(\tilde{\phi}^+(x_5)\right) = 0.59.$$

Also,

$$S\left(\tilde{\phi}^-(x_1)\right) = 0.66,\ S\left(\tilde{\phi}^-(x_2)\right) = 0.71,$$

$$S\left(\tilde{\phi}^-(x_3)\right) = 0.58,\ S\left(\tilde{\phi}^-(x_4)\right) = 0.71,$$

$$S\left(\tilde{\phi}^-(x_5)\right) = 0.72.$$

Step 3.6: Make the final ranking by using Eq. (20) and end process:

$$\phi(x_1) = S\left(\tilde{\phi}^+(x_1)\right) - S\left(\tilde{\phi}^-(x_1)\right) = 0.66 - 0.66 = 0.00,$$
$$\phi(x_2) = S\ \left(\tilde{\phi}^+(x_2)\right) - S\left(\tilde{\phi}^-(x_2)\right) = 0.63 - 0.71 = -0.08\ ,$$
$$\phi(x_3) = S\left(\tilde{\phi}^+(x_3)\right) - S\left(\tilde{\phi}^-(x_3)\right) = 0.74 - 0.58 = 0.16,$$
$$\phi(x_4) = S\left(\tilde{\phi}^+(x_4)\right) - S\left(\tilde{\phi}^-(x_4)\right) = 0.67 - 0.71 = -0.04,$$
$$\phi(x_5) = S\left(\tilde{\phi}^+(x_5)\right) - S\left(\tilde{\phi}^-(x_5)\right) = 0.59 - 0.72 = -0.13,$$

Table 6
Comparison of N-PROMETHEE with other existing methods.

MCDM techniques	Alternatives					Ranking	Feasible choice
	x_1	x_2	x_3	x_4	x_5		
N-PROMETHEE (proposed)	2	4	1	3	5	$x_3 > x_1 > x_4 > x_2 > x_5$	x_3
IF-PROMETHEE [33]	1	5	2	3	4	$x_1 > x_3 > x_4 > x_5 > x_2$	x_1
SHFRS [40]	5	1	2	3	4	$x_2 > x_3 > x_4 > x_5 > x_1$	x_2

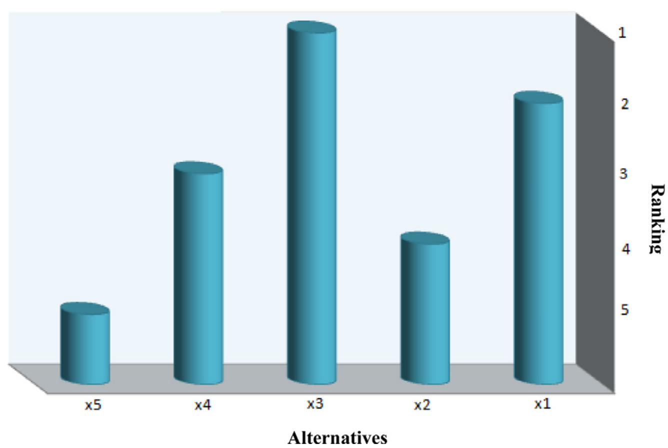


Fig. 3. The ranking of alternatives.

Then, $x_3 > x_1 > x_4 > x_2 > x_5$.

So, the Deep packet inspection is the most important security service of FMEC according to decision makers opinions. The ranking of alternatives appears in Fig. 3.

4.1. Comparative analysis

In this subsection, we compare the suggested N-PROMETHEE with other existing multi-criteria decision making techniques under intuitionistic fuzzy environment.

The ranking of security service alternatives in FMEC using different techniques presented in Table 6.

It's obvious that the N-PROMETHEE technique is correlated moderately with the IF-PROMETHEE [33], and has a weak correlation with SHFRS [40]. This variation returns to the formulation nature of these techniques. The two other techniques also didn't consider the indeterminacy degree in their calculations and this also affect the results. So, the obtained decision of two other methods is not precise.

The proposed algorithm has the following advantages:

- The proposed method help decision makers to evaluate alternatives using linguistic values. It also simplifying decision process via providing an aggregation method which able to aggregate linguistic values simply and easily.
- We provide a formula for calculating indeterminacy degree unlike the methods in [33,40].
- In our algorithm we considers the truth, indeterminacy and falsity degrees in our calculations, so we can simulate reality effectively and then obtain more precise decisions.
- Our proposed algorithm uses neutrosophic values as inputs which are more accurate than fuzzy and crisp values.
- Using proposed model able to handle vague, inconsistent and indeterminate information.
- Our proposed algorithm is easy, simple and can be applied in different fields.

5. Concluding remarks

In this research, we have presented an outranking technique, PROMETHEE and expanded it into the context of neutrosophic set. Our proposed N-PROMETHEE takes not only neutrosophic preferences, but also neutrosophic weights. The algorithm of N-PROMETHEE has been given for the appropriateness of application. Because neutrosophic sets able to represent perception and cognition of humans, our suggested N-PROMETHEE presents simpler application in helping the decision makers to solve MCDM problems without immolating any benefit of the traditional PROMETHEE technique. Although the MCDM problem which concerns the estimation and ranking of alternative security services for FMEC has been carried out to exemplify the applicability and efficiency of our suggested method, our expanded N-PROMETHEE can be applied in any other domains of MCDM. The N-PROMETHEE has been compared with IF-PROMETHEE. The N-PROMETHEE can represent the preferences from three sides (i.e., preferred (truth membership degree), non-preferred (falsity membership degree) and indeterminacy), which guarantee the preference information more comprehensive. The N-PROMETHEE suggested in this research can offer a affluent framework than the conventional PROMETHEE and IF-PROMETHEE.

Limitation of proposed research

More involvements from more companies will make our research better.

Competing interests

The authors announce that there is no discrepancy of interests concerning the publication of this research.

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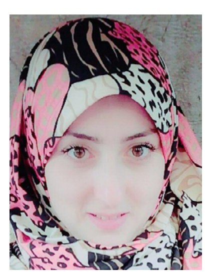

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