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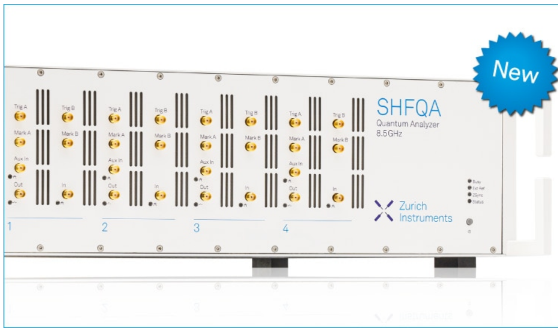

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Single Valued Trapezoidal Neutrosophic Multi - Criteria Decision Making Problems - PROMETHEE II

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Abstract. Decision making is a continuous and necessary part of the management of any organization or business activity. By solving the uncertain multi criteria decision making problems we can choose more reliably from the incomplete and complex information in real life dynamic from the decision makers. In this work, we discussed the PROMETHEE-II(Preference Ranking Organization Method For Enrichment Evaluation) for dealing with the Multi Criteria Decision Making problems with Single Valued Trapezoidal Neutrosophic Fuzzy Set in which the multiple alternatives are implemented by the decision makers with respect to the related criteria and the weights are completely unknown. Besides, the criteria weights are estimated based on the pairwise comparison of the criteria. By applying the PROMETHEE-II method, we get a partial and complete ranking order of the alternatives.

INTRODUCTION

Neutrosophic set is the popularization of the intuitionistic fuzzy set by *Florentin Smarandache* in 1995. Neutrosophical set is a powerful general framework that generates the classical set, fuzzy set and vague set concepts.The term neutrosophy was originated into *neutrosophic* and *Broumi et al* proposed the concept of fuzzy neutrosophic set. *Bansall et al., 2015* [2] Neutrosophical set is a part of neutrosophy which studies the source, existence and range of neutralities, as well as their interactions with numerous conceptual spectra. *Liang et al., 2018* suggested the neutrosophic set approach to explicit the indeterminacy and unpredictable information which occurs in the real world. The neutrosophic set is described by the three degrees as Truth membership(T), Indeterminacy membership(I) and Falsity membership(F), whose values are standard unit or non-standard unit $]^{-}0, 1^{+}[$.

Single valued neutrosophic set is a subset of the neutrosophic set *Deli et al., 2016*. It is an representation of the neutrosophic set that can be used in real applications in science and technology. *Ling et al., 2018* [10, 11] introduced the single valued neutrosophic elegant fuzzy set for handling the multi criteria decision making. *Afshari et al., 2019* [1] introduced the single valued neutrosophic set to the DEMATEL method. While taking into account the interrelationships between factors, DEMATEL is used to acquire the significance and cause-effect relationships between the powerful factors of coastal erosion. *Mohammed et al., 2018* [12] comibened two sets would tackle all forms of data and information vagueness, complexity and incompleteness, and then improve the quality of the services and decisions delivered to their residents from smart cities.

Neutrosophic set provides an effective tool for single-valued neutrosophic soft set, that accomodate uncertainities *Ren S., 2017* [16]. Here the aggregation operators were used. Analyzing the Single-Valued and two Single-Valued Neutrosophic weight arithmetic averaging operator based on real life applications *Riad et al., 2016*. Intuitionistic fuzzy sets(*IFS*) were used to correlate with Neutrosophic set *Liao H., 2014*. MVNNWA(*Multi Valued Neutrosophic Number Weighted Averaging*) and MVNNWG(*Multi Valued Neutrosophic Number Weight Geometric*) operators are utilized to compare and to find the rank over all the alternatives *Ye J., 2014* [19, 20]. Handling the indeterminacy of degrees in Neutrosophic Sets are Vague. Neutrosophic Analytic Hierarchy Process has been developed by *Nouran et al.,(2000)* [14] to determine the weights by the pairwise comparison over the criteria to attain the best solution. *Liang et al.,(1992)* [10] introduced the aggregation operators and the linguistic variables to find out the criteria weights. To find the ranking, combine the subjective and objective ranking values. The calculations, triangular fuzzy numbers and trapezoidal fuzzy numbers can also be estimated by the computer. *Broumi and Smarandache (2015)* developed the Neutrosophic Set with the Single-Valued Neutrosophic Soft Set and some applications are applied in these sets in decision-making.

Karsak ., 2002 [8] introduced the distance based approach to MCDM from the ideal and anti-ideal weighted distances, not only these distances cannot conclude to acquire the rank. *Halouani et al.,(1995)* [6] developed the PROMETHEE I and II approach with the linguistic variables to compromise with the fusion methodology by the

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heterogeneous frameworks, and later this methodology has been applied with 2-tuple linguistic values. *Parthiban et al., 2012*[19] [15] estimates the supplier selection for an automotive industry, that collobrates between the element and it computes with factor. Supply selection is made based on the capability of the data. Final selection is done by the decision experts.

PROMETHEE Method was generally first developed in 1980's. The basic elements of this method were introduced by Professor Jean-Pierre Brans in 1982. After that some extensions were developed on this method by Professor Jean-Pierre Brans and Professor Bertrand Mareschal. It is valid over the preference function. PROMETHEE-I method yields the partial ordering of the alternatives, while the PROMETHEE-II method provide the entire ranking of the decision alternatives. The mathematical part is given in the algorithm for single valued trapezoidal neutrosophic number PROMETHEE-II method. *Shemshadi et al.,2011* [17] popularized the integrated approach for Dematel method in the food supply chain performance. The important target of supply chain is to gratify the both representative and the purchaser. To Solve the real life problems we use the sequence of Neutrosophic Set and Soft Set.

PRELIMINARIES

Definition .1. *Let Z be a non-empty set. A fuzzy set $'S'$ in the universe of data U can be defined as the set of ordered pairs and it can be expressed as:*

$$S = \Big\{(z, \mu_S(z))/z \in U\Big\}$$

where $\mu_S(z)$ is the degreee of membership of the element z in the fuzzy set $'S'$ for each $z \in Z$. It assumes the value between 0 and 1. (i.e) $\mu_S(z) \in [0,1]$.

Definition .2. *Let A be a subset of the universe of dicourse U. An element $'x'$ be the Neutrosophic Set with respect to the Truth membership (T^*), Indeterminacy membership (I^*) and Falsity membership (F^*) where T^* , I^* , F^* : $A \to [0,1]$.*
The Neutrosophic Set N can be represented as follows :

$$N = \Big\{\big\langle x, (T^*(x), I^*(x), F^*(x))\big\rangle / x \in U\Big\} \tag{1}$$

Since $T'(x), I'(x), F'(x)$ be the subset of $]^-0, 1^+[$.

Definition .3. *Let U be the Universe of the discourse. An element $'x'$ is denoted by the single valued neutrosophic set .*

A Single Valued Neutrosophic Set R in U is expressed by

$$R = \Big\{\big\langle x, (T'(x), I'(x), F'(x))\big\rangle / x \in U\Big\} \tag{2}$$

where $T'(x), I'(x), F'(x) \in [0,1]$
For all $x \in U$, $T'(x), I'(x), F'(x) \in [0,1]$ and $0 \le T'(x) + I'(x) + F'(x) \le 3$.

Definition .4. *Let $G = \Big\langle \big[v_1, v_2, v_3, v_4\big], T^*(x), I^*(x), F^*(x) \Big\rangle$ be a Single Valued Trapezoidal Neutrosophic Set (SVTNN). A score function S(G) can be represented as follows :*

$$S(G) = \Big(v_1 + v_2 + v_3 + v_4 * \big[1 + T^*(x) - 2I^*(x) - F^*(x)\big]\Big)/8 \tag{3}$$

Definition .5. *Let $V = \Big\langle \big[v_1, v_2, v_3, v_4\big], T'(x), I'(x), F'(x) \Big\rangle$ be a special SVTNN on the set R and let 'x' be the element, where truth-membership function $T'_v(x)$, indeterminacy-membership function $I'_v(x)$ and falsity membership function $F'_v(x)$ are represented as follows:*

$$T'_v(x) = \begin{cases} \frac{\big(x-v_1\big)T'(v)}{v_2-v_1} & if \quad (v_1 < x < v_2) \\ T'(v) & if \quad (v_2 < x < v_3) \\ \frac{\big(v_4-x\big)T'(v)}{v_4-v_3} & if \quad (v_3 < x < v_4) \\ 0 & otherwise, \end{cases}$$

$$I'_v(x) = \begin{cases} \frac{\left(v_2 - x + I'(v)[x - v_1]\right)}{v_2 - v_1} & if \quad (v_1 < x < v_2) \\ I'(v) & if \quad (v_2 < x < v_3) \\ \frac{\left(x - v_3 + I'(v)[v_4 - x]\right)}{v_4 - v_3} & if \quad (v_3 < x < v_4) \\ 1 & otherwise, \end{cases}$$

$$F'_v(x) = \begin{cases} \frac{\left(v_2 - x + F'(v)[x - v_1]\right)}{v_2 - v_1} & if \quad (v_1 < x < v_2) \\ F'(v) & if \quad (v_2 < x < v_3) \\ \frac{\left(x - v_3 + F'(v)[v_4 - x]\right)}{v_4 - v_3} & if \quad (v_3 < x < v_4) \\ 1 & otherwise. \end{cases}$$

If $v_4 > 0$, then the positive Single Valued Trapezoidal Neutrosophic Number be $V = \left\langle [v_1, v_2, v_3, v_4], T'(v), I'(v), F'(v) \right\rangle$, denoted by $V > 0$. Correspondingly, when $v_4 \leq 0$, then the negative Single Valued Trapezoidal Neutrosophic Number be $V = \left\langle [v_1, v_2, v_3, v_4], T'(v), I'(v), F'(v) \right\rangle$, denoted by $V \leq 0$.

Problem Description

Let $B = \{B_1, B_2, ..., B_m\}$ be the $'m'$ alternatives which are estimated by the respective $'n'$ criteria $E = \{E_1, E_2, ..., E_n\}$. The estimated values are transformed into SVTNN's and V_{ij} represents the estimated values for the options $B_i(i = 1, 2, 3, ..., m)$ concealed by the criterion $E_j(j = 1, 2, 3, ..., n)$. The decision matrix is transformed from the estimated values provided by the decision makers, can be denoted as V:

Step 1:

Construct the Single Valued Trapezoidal Neutrosophic fuzzy decision matrix,

$$V = \begin{bmatrix} V_{11} & V_{12} & \cdots & V_{1n} \\ V_{21} & V_{22} & \cdots & V_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ V_{m1} & V_{m2} & \ldots & V_{mn} \end{bmatrix}$$

Each criteria has specific weight, the weight vector of criteria is $W = (w_1, w_2, ..., w_n)^T$ where $w_k \geq 0$ (k = 1,2,....,n) and $\sum_{k=1}^{n} w_k = 1$.

Step 2:

Normalize the decision matrix of the alternative B_i under the given criterion E_j by using the following equation:

$$G_{ij} = \left\langle \left[1 - V_4^{ij}, 1 - V_3^{ij}, 1 - V_2^{ij}, 1 - V_1^{ij}\right], T^*(V^{ij}), I^*(V^{ij}), F^*(V^{ij}) \right\rangle. \quad (4)$$

It is clear that the normalized values G_{ij} are also SVTNN's.

Step 3:

Acquire the score values by using the score function in (3), we access the score value $S(G_{ij})(i = 1, 2, ..., m; j = 1, 2, ..., n)$ of the alternatives B_i regarding the criterion E_j.

Step 4 :

Determine the evaluative differences of the i^{th} alternative in spite of the other alternatives. Differences in the criteria values are calculated between different alternatives pairwise.

Step 5 :

Determine the Preference function $R_j(i, i')$. The simplified preference function is defined as follows:

$$Q_j(i, i') = 0 \qquad if \quad G_{ij} \leq G_{i'j} \quad (5)$$

$$Q_j(i,i') = (G_{ij} - G_{i'j}) \quad if \;\; G_{ij} \geq G_{i'j} \tag{6}$$

Step 6 :

The weight of each criterion (w_c) is determined. AHP(Analytic Hierarchy Process) method is used in this paper. This method was introduced by Saaty(1980). It depends on the pairwise comparison of criteria.

Step 7 :

Determine the aggregated preference function by taking details of the criteria weights. The preference function on each criterion will be aggregated as following:

$$\delta(i,i') = \left[\sum_{j=1}^{m} w_j.Q_j(i,i')\right] / \sum_{j=1}^{m} w_j. \tag{7}$$

where w_j serve as the relative importance (weight) of the j^{th} criterion.

Step 8 :

Regulate the positive and Negative flows for each alternative as follows:
Positive (or leaving) flow for i^{th} alternative is described as follows :

$$\psi^+(i) = 1/n - 1 \sum_{i'=1}^{n} \delta(i,i') \tag{8}$$

Negative (or entering) flow for i^{th} alternative is described as follows :

$$\psi^-(i) = 1/n - 1 \sum_{i'=1}^{m} \delta(i,i') \tag{9}$$

where n is the number of alternative and $(n-1)$ is the number of the other alternatives.

Step 9 :

Determine the net outranking flow $\psi(i)$ to produce the overall preference degrees of the alternative i and i'.

$$\psi(i) = \psi^+(i) - \psi^-(i) \tag{10}$$

Step 10 :

Determine the ranking of all the given alternatives B_i depends on the net flow $\psi(i)$. The best alternative is calculated as the greater value in $\psi(i)$.

ILLUSTRATIVE EXAMPLE

In this section we describe the supplier selection application for the proposed mathematical method. Supplier Selection plays a significant role in supply chain management, in behalf of growing global involvement in environment stability. In general, green production becomes an important aspect for every manufacturers. Automotive plays an crucial role in India with United kingdom[3]. Its the largest economic region in the revenue. India auto industry places a 4th largest in the world with 9.5percent year-on-year. It absorbs a large number of manufacturing companies and institution, that concerns the design, development, corporation, marketing and selling of the motor vehicles. For selecting a best motor vehicle, we wish to compile with supplier selection analysis. While selecting the best one, the decision makers must focus on the company capabilities and fitness. The selection is considered for the Business and Personal facilities.

Product and Quality (E_1)

The main focus in Supplier Selection is the thing of product quality, product safety, system quality and loading the quality products. Decision makers need to see the design and development in the product quality. The universal goal of all decision makers in supply chain is to provide the best product and quality.

Cost (E_2)

Cost is one of the important criteria in supplier selection. Thus decision makers have to choose the best quality product containing all competence with the comfortable price. The cost element contributes to economic growth as price and contribution.

Public Satisfaction (E_3)

Once the product has introduced or developed, it must be entirely satisfied by the purchaser.

Technology (E_4)

Technical operations be one of the significant feature in supply chain management. Quality of each products can be vary with automotives different and it must access the proper technical operations.

Service (E_5)

Best service to the customer results in customer satisfaction and it concerns with the on-time delivery, delivery speed and fast reply to the purchaser.

MAIN RESULT

The Decision matrix is formed using the SVTNN shown in Table I. This result matrix has five alternatives and five criteria.

TABLE I. Neutrosophic trapezoidal decision matrix

	E_1	E_2	E_3	E_4	E_5
B_1	⟨(0.4,0.5,0.6,0.7), 0.3,0.4,0.5⟩	⟨(0.1,0.15,0.2,0.25), 0.3,0.4,0.5⟩	⟨(0.5,0.6,0.7,0.8), 0.3,0.4,0.6⟩	⟨(0.4,0.5,0.6,0.7), 0.2,0.4,0.7⟩	⟨(0.2,0.3,0.35,0.4), 0.1,0.15,0.2⟩
B_2	⟨(0.6,0.7,0.8,0.9), 0.3,0.5,0.7⟩	⟨(0.5,0.6,0.7,0.8), 0.2,0.3,0.4⟩	⟨(0.4,0.45,0.5,0.7), 0.2,0.4,0.7⟩	⟨(0.5,0.6,0.7,0.9), 0.4,0.5,0.55⟩	⟨(0.5,0.6,0.65,0.7), 0.3,0.4,0.5⟩
B_3	⟨(0.1,0.25,0.3,0.4), 0.4,0.5,0.6⟩	⟨(0.2,0.3,0.5,0.6), 0.4,0.45,0.5⟩	⟨(0.5,0.6,0.7,0.8), 0.3,0.4,0.5⟩	⟨(0.3,0.4,0.5,0.7), 0.2,0.3,0.4⟩	⟨(0.1,0.2,0.3,0.4), 0.2,0.3,0.35⟩
B_4	⟨(0.3,0.4,0.5,0.6), 0.1,0.4,0.8⟩	⟨(0.1,0.3,0.4,0.5), 0.3,0.4,0.6⟩	⟨(0.1,0.3,0.5,0.7), 0.3,0.4,0.5⟩	⟨(0.6,0.7,0.8,0.9), 0.2,0.4,0.6⟩	⟨(0.2,0.4,0.5,0.6), 0.2,0.3,0.4⟩
B_5	⟨(0.2,0.25,0.3,0.4), 0.2,0.4,0.5⟩	⟨(0.3,0.4,0.5,0.6), 0.3,0.35,0.4⟩	⟨(0.2,0.3,0.4,0.5), 0.1,0.3,0.5⟩	⟨(0.5,0.6,0.7,0.8), 0.1,0.2,0.3⟩	⟨(0.3,0.5,0.55,0.6), 0.4,0.5,0.6⟩

The Neutrosophic decision matrix is normalized by using (4) and their values are given in Table II. The score function of the single valued trapezodial neutrosophic set is determine by using (3). The values of the score function are given in Table III.

TABLE II. Neutrosophic trapezoidal normalized matrix

	E_1	E_2	E_3	E_4	E_5
B_1	⟨(0.4,0.5,0.6,0.7), 0.3,0.4,0.5⟩	⟨(0.1,0.15,0.2,0.25), 0.3,0.4,0.5⟩	⟨(0.5,0.6,0.7,0.8), 0.3,0.4,0.6⟩	⟨(0.4,0.5,0.6,0.7), 0.2,0.4,0.7⟩	⟨(0.2,0.3,0.35,0.4), 0.1,0.15,0.2⟩
B_2	⟨(0.6,0.7,0.8,0.9), 0.3,0.5,0.7⟩	⟨(0.5,0.6,0.7,0.8), 0.2,0.3,0.4⟩	⟨(0.4,0.45,0.5,0.7), 0.2,0.4,0.7⟩	⟨(0.5,0.6,0.7,0.9), 0.4,0.5,0.55⟩	⟨(0.5,0.6,0.65,0.7), 0.3,0.4,0.5⟩
B_3	⟨(0.1,0.25,0.3,0.4), 0.4,0.5,0.6⟩	⟨(0.2,0.3,0.5,0.6), 0.4,0.45,0.5⟩	⟨(0.5,0.6,0.7,0.8), 0.3,0.4,0.5⟩	⟨(0.3,0.4,0.5,0.7), 0.2,0.3,0.4⟩	⟨(0.1,0.2,0.3,0.4), 0.2,0.3,0.35⟩
B_4	⟨(0.3,0.4,0.5,0.6), 0.1,0.4,0.8⟩	⟨(0.1,0.3,0.4,0.5), 0.3,0.4,0.6⟩	⟨(0.1,0.3,0.5,0.7), 0.3,0.4,0.5⟩	⟨(0.6,0.7,0.8,0.9), 0.2,0.4,0.6⟩	⟨(0.2,0.4,0.5,0.6), 0.2,0.3,0.4⟩
B_5	⟨(0.2,0.25,0.3,0.4), 0.2,0.4,0.5⟩	⟨(0.3,0.4,0.5,0.6), 0.3,0.35,0.4⟩	⟨(0.2,0.3,0.4,0.5), 0.1,0.3,0.5⟩	⟨(0.5,0.6,0.7,0.8), 0.1,0.2,0.3⟩	⟨(0.3,0.5,0.55,0.6), 0.4,0.5,0.6⟩

Estimating the differences in the criteria values over the alternatives pairwise.The weight values of SVTN is determine by using weighted AHP. The values of normalized weighted AHP is given below:

$$W_1 = 0.263, \quad W_2 = 0.159, \quad W_3 = 0.097, \quad W_4 = 0.419, \quad W_5 = 0.062.$$

The weighted AHP value sum should be in 1 and the weighted normalized score matrix values given in Table IV. The weighted graphical picture is shown in the below figure.

The preference functions can be calculated by using (5) and (6) and the aggregated preference function are shown in Table V by using (7).

TABLE III. Neutrosophic trapezoidal score matrix

	E_1	E_2	E_3	E_4	E_5
B_1	0	0	-0.0175	-0.0675	0.2063
B_2	-0.0500	0.0350	-0.0731	-0.0244	0
B_3	-0.0738	0	0	0.0525	0.0937
B_4	-0.1375	-0.0337	0	-0.0250	0.0575
B_5	-0.0356	0.0550	0	0.0700	-0.0513

TABLE IV. Normalization of the Weighted Score Matrix

	w_1	w_2	w_3	w_4	w_5	w_c
w_1	0.247	0.294	0.286	0.222	0.267	0.263
w_2	0.123	0.147	0.190	0.133	0.2	0.159
w_3	0.074	0.074	0.095	0.111	0.133	0.097
w_4	0.494	0.441	0.381	0.444	0.333	0.419
w_5	0.062	0.044	0.048	0.089	0.067	0.062

TABLE V. Aggregation of the preference function

	Q_1	Q_2	Q_3	Q_4	Q_5
Q_1	-	0.314	0.264	0.0508	0.0254
Q_2	0.0237	-	0.0119	0.0342	0.0032
Q_3	0.0520	0.0451	-	0.0359	0.0090
Q_4	0.0195	0.0107	0	-	0.0067
Q_5	0.0680	0.0537	0.0260	0.0807	-

The leaving flows and entering flows can be evaluated by using the equations (8),(9) are shown in Table VI. Utilizig the equation (10), net flows are evaluated and ranking the alternatives are shown in Table VII.

Fig:1 indicates the graphical representation of ranking and net flows. According to the five criteria and five alternatives of the selected automotive industry, the alternative B_3 is the leading automotive industry among the other alternatives. The best automotive industry in india is B_3.

$$B_3 > B_5 > B_1 > B_2 > B_4$$

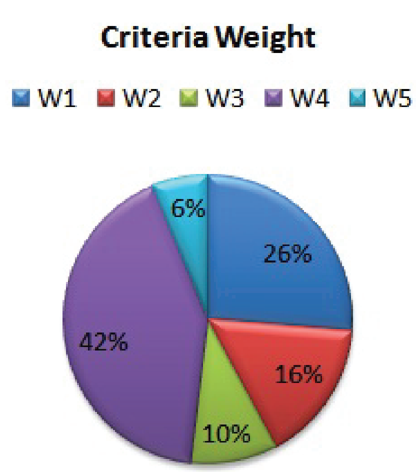

TABLE VI. Values of the Leaving and Entering Flow

Location	Leaving Flow (ψ^+)	Entering Flow (ψ^-)
Q_1	0.0335	0.0408
Q_2	0.0183	0.0352
Q_3	0.0355	0.0161
Q_4	0.0092	0.0504
Q_5	0.0571	0.0111

TABLE VII. Ranking and net flow

Location	Net outranking flow (ψ)	Rank
Q_1	-0.0073	III
Q_2	-0.0169	IV
Q_3	0.0194	I
Q_4	-0.0412	V
Q_5	0.0460	II

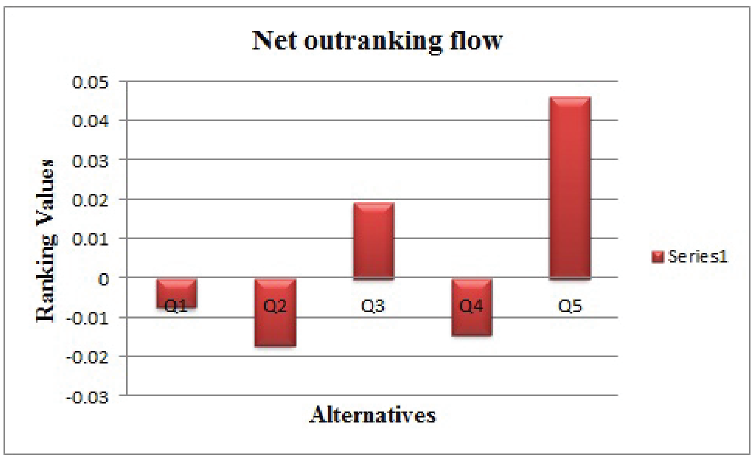

FIGURE 1. Net outranking flow of PROMETHEE II METHOD

CONCLUSION

Multi criteria decision making has been one of the quick flourishing problem areas in those method. The present work solves the Multi Criteria Decision Making problems with the PROMETHEE-II Method and we suggested the Neutrosophic Sets to the Single-Valued Neutrosophic Sets based on the Fuzzy AHP and Fuzzy PROMETHEE-II. The prospective PROMETHEE-II method is very clear and decision makers can easily understand. Comparing to the other MCDM methods the PROMETHEE-II has high efficiency and capacity to tolerate many criteria. Simplicity, consistency and reliability are the fundamental issues of this method. It processes data at the same time both the statistical and analytical. The New Single-Valued Trapezoidal Neutrosophic Set approaches a profitable way to find out the incoming and outgoing flows by the Multi Criteria Decision Making problems that can acquire from the robotics, supplier selection and some other facet.

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