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Interval-valued Neutrosophic Pythagorean Sets and their Application in Decision Making using IVNP-TOPSIS

Stephy Stephen[1], M.Helen[2]

Research Scholar, Department of Mathematics, Nirmala College for Women, Red Fields, Coimbatore, India[1]

Associate Professor, Department of Mathematics, Nirmala College for Women, Red Fields, Coimbatore, India[2]

ABSTRACT: Vagueness and imprecision exist in every discipline, and many academics have been attempting to incorporate the concept of vagueness and uncertainty into problems to overcome these. In this article, a new concept called Interval-valued Neutrosophic Pythagorean set with dependent interval-valued Pythagorean components is introduced. The notion of neutrosophy was created to overcome the uncertainty that exists in real-world circumstances. In particular, the Pythagorean fuzzy set was proven to be an interesting tool to compute uncertainty. As vagueness exists in every real-world problem and to solve problems by taking into consideration this vagueness, we have introduced interval-valued neutrosophic Pythagorean sets with dependent interval valued Pythagorean components and some of its properties.We have also analyzed about how it may be used in multi-attribute decision-making challenges.

KEYWORDS: interval-valued neutrosophic Pythagorean sets, neutrosophy, multi attributes, decision making, score function.

I. INTRODUCTION

Due to its necessity and consistency, decision-making is making its way into the research realm, where it is being used in a variety of applications.The evolution of Pythagorean fuzzy sets and their applications and its varied generalized forms in these days isthe main talk among researchers. The main highlight of the Pythagorean sets is the square of their membership value lying between 0 and 1. This makes it easy to compute and highly reliable. As uncertainty is prevailing in every task that we undertake,the data we gather does not always match the precision of the values; so, the use of neutrosophy and Pythagorean sets aids us in keeping up with the precision of the values. In this research article, the concepts of neutrosophy, Pythagorean concept, and taking into consideration of interval values are combined together to approach the best results. Technique for Order of Preference by Similarity to Ideal Solution TOPSIS method is the multi criteria decision making technique used to choose the alternative that is in close association with the best ideal solution and in far association with the worst ideal solution.

In this research article, Section II deals with the review of literature followed by preliminary concepts in section III. In section IV, we have introduced the new Interval-Valued Neutrosophic Pythagorean sets and its operators. In Section V, we have proposed the algorithm for the integration of TOPSIS with interval-valued neutrosophic Pythagorean followed by an example in Section VI. The conclusion of the results obtained are expressed in section VII and are compared with the existing results.

II. RELATED WORK

Zadeh[18] pioneered the fuzzification of crisp values in 1965. Membership values ranging from [0,1] were allocated, and only true membership values were considered.In 1975, Zadeh[19] proposed interval fuzzy sets to explain about the impreciseness in problems. Further advancements were achieved, and Atanassov[2] introduced the notion of intuitionistic fuzzy sets in 1986, which centered around membership and non-membership values. Both the membership and non-membership values fall inside the range [0,1].This concept was further established with truth membership, indeterminacy and false membership values as Neutrosophic set by Florentin Smarandache[3],[7],[13-14] in the year 1995. The membership values range from 0 to 1. He discussed about interval-valued neutrosophic sets and its

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nature.Because of the presence of indeterminacy, its application is extensively employed in numerous disciplines such as decision webs and multi-criteria decision-making procedures.

Multi attribute decision-making with the aid of interval neutrosophic sets was studied by Nafei et al[1]. Yager[17]outlined the Pythagorean fuzzy set (PFS) as the square of the membership value and the non-membership value being less than or equal to 1. Stephy Stephen et al [15] worked with linear programming by making use of Interval-Valued trapezoidal neutrosophic sets. Zhang et al[20] investigated the use of the TOPSIS approach to examine multiple criterion decision making, with a Pythagorean fuzzy set used to solve uncertainty.Garg[4-6] continued to improve the accuracy and scoring function of interval valued Pythagorean fuzzy sets to tackle decision making tasks using TOPSIS.Peng et al[8],[16] imposed some properties on interval valued Pythagorean fuzzy set and discussed its usage in decision making problems with the help of aggregation operators. In the year 2021, Radha and Stanis Arul Mary[9-11] proposed the idea of pentapartitioned neutrosophic Pythagorean sets and quadripartitioned neutrosophic Pythagorean sets, as well as their improved correlation utilising Pythagorean sets. Jhansi et al[12] came forward in introducing measures of correlation with Pythagorean neutrosophic sets with dependent neutrosophic components.

III. PRELIMINARIES

DEFINITION 3.1[3] :

Let X be a universe. A neutrosophic set A_N in X is defined by a truth membership function, an indeterminacy membership function and falsity membership function. $T(A_N)$, $I(A_N)$, $F(A_N)$ are the truth, indeterminacy and falsity membership functions and they are real non-standard subsets of $]0^-, 1^+[$ and $0^- \leq T(A_N) \leq \sup\ I(A_N) \leq \sup F(A_N) \leq 3^+$

DEFINITION 3.2[15]:

Let $A = [(a_1, a_2, a_3, a_4); \mu_A, \vartheta_A, \gamma_A]$ and $B = [(b_1, b_2, b_3, b_4); \mu_B, \vartheta_B, \gamma_B]$ be two trapezoidal neutrosophic numbers, where $\mu_A, \vartheta_A, \gamma_A$ and $\mu_B, \vartheta_B, \gamma_B$ are the truth membership degree, indeterminacy membership degree and falsity membership degree of the trapezoidal neutrosophic number A and B respectively. The mathematical operations between A and B are defined as:

$$A + B = [(a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \mu_A \wedge \mu_B, \vartheta_A \vee \vartheta_B, \gamma_A \vee \gamma_B]$$
$$A - B = [(a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4); \mu_A \wedge \mu_B, \vartheta_A \vee \vartheta_B, \gamma_A \vee \gamma_B]$$
$$kA = \begin{cases} [(ka_1, ka_2, ka_3, ka_4); \mu_A, \vartheta_A, \gamma_A] & k > 0 \\ [(ka_4, ka_3, ka_2, ka_1); \mu_A, \vartheta_A, \gamma_A] & k < 0 \end{cases}$$

where ' ∧ ' and ' ∨ ' are the maximum and minimum operators respectively.

INS: Interval neutrosophic set:

DEFINITION 3.3[15]:

An interval-valued trapezoidal neutrosophic set $A = [(a_1, a_2, a_3, a_4); [\mu_A^L, \mu_A^U], [\vartheta_A^L, \vartheta_A^U], [\gamma_A^L, \gamma_A^U]$ and $B = [(b_1, b_2, b_3, b_4); [\mu_B^L, \mu_B^U], [\vartheta_B^L, \vartheta_B^U], [\gamma_B^L, \gamma_B^U]$ be two interval valued trapezoidal numbers with $[\mu_A^L, \mu_A^U], [\vartheta_A^L, \vartheta_A^U], [\gamma_A^L, \gamma_A^U]$ and $[\mu_B^L, \mu_B^U], [\vartheta_B^L, \vartheta_B^U], [\gamma_B^L, \gamma_B^U]$ being the upper and lower bound for the truth, indeterminacy and falsity membership degrees for the sets A and B.

The mathematical operations between A and B can be represented as:

$$A + B = [(a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); [\mu_A^L + \mu_B^L - \mu_A^L\mu_B^L, \mu_A^U + \mu_B^U - \mu_A^U\mu_B^U], [\vartheta_A^L\vartheta_B^L, \vartheta_A^U\vartheta_B^U], [\gamma_A^L\gamma_B^L, \gamma_A^U\gamma_B^U]$$
$$A - B = [(a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4); [\mu_A^L + \mu_B^L - \mu_A^L\mu_B^L, \mu_A^U + \mu_B^U - \mu_A^U\mu_B^U], [\vartheta_A^L\vartheta_B^L, \vartheta_A^U\vartheta_B^U], [\gamma_A^L\gamma_B^L, \gamma_A^U\gamma_B^U]$$

PYTHAGOREAN NEUTROSOPHIC SET:

DEFINITION 3.4[10]:

Pythagorean neutrosophic set is a generalization of neutrosophic set with dependent neutrosophic components and Pythagorean fuzzy set with some specific conditions.

Let X be a universe. A PythagoreanNeutrosophicset A with T and F are dependent neutrosophic components and I as independent component for $A = \{< x, T_A, I_A, F_A >: x \in X\}$ on X is an object of the form

$$(T_A)^2 + (I_A)^2 + (F_A)^2 \leq 2$$

Here,$T_A(x)$ is the truth membership, $I_A(x)$ is indeterminancy membership and$F_A(x)$ is the false membership.

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IV. INTERVAL VALUED NEUTROSOPHIC PYTHAGOREAN SET WITH EPENDENT INTERVAL VALUED NEUTROSOPHIC COMPONENTS

DEFINITION 4.1:

An Interval-valued neutrosophic Pythagorean set having truth T and falsity F as dependent interval-valued neutrosophic components and indeterminacy I as independent interval-valued neutrosophic component in an universe S can be defined as

M= $\{< s, [T_M^L, T_M^U], [I_M^L, I_M^U], [F_M^L, F_M^U] >; s \in S\}$ on S having the form $\left[\frac{T_M^L+T_M^U}{2}\right]^2 + \left[\frac{I_M^L+I_M^U}{2}\right]^2 + \left[\frac{F_M^L+F_M^U}{2}\right]^2 \leq 2$.

Here $[T_M^L, T_M^U], [I_M^L, I_M^U], [F_M^L, F_M^U]$ represents the lower and upper bound of the truth, indeterminacy and falsity membership degrees.

DEFINITION 4.2:

The complement of an interval-valued neutrosophic Pythagorean set M= $\{< s, [T_M^L, T_M^U], [I_M^L, I_M^U], [F_M^L, F_M^U] >; s \in S\}$ with dependent interval-valued neutrosophic Pythagorean components is $M^C = \{ <s, [F_M^L, F_M^U], [1 - I_M^L, 1 - I_M^U], [T_M^L, T_M^U] >; s \in S\}$

DEFINITION 4.3:

Let M= $\{ <s, [T_M^L, T_M^U], [I_M^L, I_M^U], [F_M^L, F_M^U] >\}$ and N= $\{ <r, [T_N^L, T_N^U], [I_N^L, I_N^U], [F_N^L, F_N^U] >\}$ be two interval-valued neutrosophic Pythagorean set with dependent interval-valued neutrosophic components, then

M+N= $\{<s+r, [T_M^L + T_N^L - T_M^L T_N^L, T_M^U + T_N^U - T_M^U T_N^U], [I_M^L I_N^L, I_M^U I_N^U], [F_M^L F_N^L, F_M^U F_N^U] >\}$

M.N = $\{<sr, [T_M^L T_N^L, T_M^U T_N^U], [I_M^L + I_N^L - I_M^L I_N^L, I_M^U + I_N^U - I_M^U I_N^U], [F_M^L + F_N^L - F_M^L F_N^L, F_M^U + F_N^U - F_M^U F_N^U] >\}$

DEFINITION 4.4:

An interval-valued neutrosophic Pythagorean sets with dependent interval-valued neutrosophic components M= $\{< s, [T_M^L, T_M^U], [I_M^L, I_M^U], [F_M^L, F_M^U] >; s \in S\}$ will be reduced to the neutrosophic Pythagorean set with dependent neutrosophic components if $T_M^L = T_M^U, I_M^L = I_M^U$ and $F_M^L = F_M^U$.

DEFINITION 4.5:

The score function, accuracy function and certainty function of an interval-valued neutrosophic Pythagorean sets with dependent interval-valued neutrosophic components I and F are defined as

$$S_M(A) = [T_M^L + (1 - I_M^U) + (1 - F_M^U), T_M^U + (1 - I_M^L) + (1 - F_M^L)$$
$$A_M(A) = [\min(T_M^L - F_M^L, T_M^U - F_M^U), \max(T_M^L - F_M^L, T_M^U - F_M^U)]$$
$$C_M(A) = T_M^L, T_M^U$$

with the condition $0 \leq \left\{\left(\frac{T_M^L+T_M^U}{2}\right)^2 + \left(\frac{I_M^L+I_M^U}{2}\right)^2 + \left(\frac{F_M^L+F_M^U}{2}\right)^2\right\} \leq 2$

ENHANCED IVNP SCORE FUNCTION:

Let M= $\{< s, [T_M^L, T_M^U], [I_M^L, I_M^U], [F_M^L, F_M^U] >; s \in S\}$. Here, for our convenience, let us assume $T_M^L = \alpha, T_M^U = \beta, I_M^L = \gamma$, $I_M^U = \delta$, $F_M^L = \rho$, $F_M^U = \sigma$ and the enhanced IVNP score function is defined as follows:

$$sc(M) = \frac{(\alpha^2 - \gamma^2 - \rho^2)(1 + \sqrt{1 - \alpha^2 - \gamma^2 - \rho^2}) + (\beta^2 - \delta^2 - \sigma^2)(1 + \sqrt{1 - \beta^2 - \delta^2 - \sigma^2})}{2}$$

SOME NEW INTERVAL VALUED NEUTROSOPHIC PYTHAGOREAN OPERATORS:

Let M,M$_1$, M$_2$ be three interval-valued neutrosophic Pythagorean sets and $\alpha > 0$, then their operators are defined as follows:

1. $$M_1 \cup M_2 = \left\{\left\langle \begin{array}{c} s, [\max(T_1^L(x), T_2^L(x)), \max(T_1^U(x), T_2^U(x))], \\ [\min(I_1^L(x), I_2^L(x)), \min(I_1^U(x), I_2^U(x))], \\ [\min(F_1^L(x), F_2^L(x)), \min(F_1^U(x), F_2^U(x))] \end{array} \right\rangle / s \in S\right\}$$
2. $$M_1 \cap M_2 = \left\{\left\langle \begin{array}{c} s, [\min(T_1^L(x), T_2^L(x)), \min(T_1^U(x), T_2^U(x))], \\ [\max(I_1^L(x), I_2^L(x)), \max(I_1^U(x), I_2^U(x))], \\ [\max(F_1^L(x), F_2^L(x)), \max(F_1^U(x), F_2^U(x))] \end{array} \right\rangle / s \in S\right\}$$

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3. $M_1 \oplus M_2 =$

$$\left\{ \left\langle \begin{matrix} s, \left[\sqrt{(T_1^L(x))^2 + (T_2^L(x))^2 - (T_1^L(x))^2 (T_2^L(x))^2}, \sqrt{(T_1^U(x))^2 + (T_2^U(x))^2 - (T_1^U(x))^2 (T_2^U(x))^2}\right], \\ [I_1^L(x) I_2^L(x), I_1^U(x) I_2^U(x)], \\ [F_1^L(x) F_2^L(x), F_1^U(x) F_2^U(x)] \end{matrix} \right\rangle / s \in S \right\}$$

4. $M_1 \otimes M_2 =$

$$\left\{ \left\langle \begin{matrix} s, [T_1^L(x) T_2^L(x), T_1^U(x) T_2^U(x)], \\ \left[\sqrt{(I_1^L(x))^2 + (I_2^L(x))^2 - (I_1^L(x))^2 (I_2^L(x))^2}, \sqrt{(I_1^U(x))^2 + (I_2^U(x))^2 - (I_1^U(x))^2 (I_2^U(x))^2}\right], \\ \left[\sqrt{(F_1^L(x))^2 + (F_2^L(x))^2 - (F_1^L(x))^2 (F_2^L(x))^2}, \sqrt{(F_1^U(x))^2 + (F_2^U(x))^2 - (F_1^U(x))^2 (F_2^U(x))^2}\right] \end{matrix} \right\rangle / s \in S \right\}$$

5. $$\alpha M = \left\{ \left\langle \begin{matrix} s, \left[\sqrt{1 - \left(1 - (T_M^L(x))^2\right)^\alpha}, \sqrt{1 - \left(1 - (T_M^U(x))^2\right)^\alpha}\right] \\ \left[(I_M^L(x))^\alpha, (I_M^U(x))^\alpha\right], \\ \left[(F_M^L(x))^\alpha, (F_M^U(x))^\alpha\right] \end{matrix} \right\rangle / s \in S \right\}$$

6. $$M^\alpha = \left\{ \left\langle \begin{matrix} s, \left[(T_M^L(x))^\alpha, (T_M^U(x))^\alpha\right], \\ \left[\sqrt{1 - \left(1 - (I_M^L(x))^2\right)^\alpha}, \sqrt{1 - \left(1 - (I_M^U(x))^2\right)^\alpha}\right], \\ \left[\sqrt{1 - \left(1 - (F_M^L(x))^2\right)^\alpha}, \sqrt{1 - \left(1 - (F_M^U(x))^2\right)^\alpha}\right] \end{matrix} \right\rangle / s \in S \right\}$$

7. $M_1 \subseteq M_2 iff$

$$\begin{matrix} M_1^L(x) \le M_2^L(x), \le M_1^U(x) \le M_2^U(x), \\ I_1^L(x) \ge I_2^L(x), I_1^U(x) \ge I_2^U(x) \\ F_1^L(x) \ge F_2^L(x), F_1^U(x) \ge F_2^U(x) \end{matrix}$$

for all s∈S.

8. Necessity operation:

   □ M ={<s, $|T_M^L(x), T_M^U(x)|$, $[\sqrt{1 - (T_M^U(x))^2}, \sqrt{1 - (T_M^L(x))^2}]$ >/s $\in S\}$

9. Possibility Operation:

   ◊ M = {<s, $\left[\sqrt{1 - (T_M^U(x))^2}, \sqrt{1 - (T_M^L(x))^2}\right], \left[\sqrt{1 - (T_M^U(x))^2}, \sqrt{1 - (T_M^L(x))^2}\right],$ $|T_M^L(x), T_M^U(x)|, |T_M^L(x), T_M^U(x)|, s \in S\}$

V. INTERVAL-VALUED NEUTROSOPHIC PYTHAGOREAN TOPSIS (IVNP-TOPSIS) MULTI ATTRIBUTE DECISION MAKING WITH ENHANCED SCORE FUNCTION

Decision-making, initially introduced by Bellman and Zadeh finds its application in varied fields. Technique for order preference by similarity to ideal solution TOPSIS happens to be one of the best techniques in decision making where the best choice is made by taking into account the distance measures from the positive ideal value and the negative ideal value. This is one of the compensatory methods. With the help of the monotonically increasing

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preference and monotonically decreasing preference, we find the best ideal solution and the worst ideal solution, thereby ranking the chosen set of choices.
Following is the algorithm for the Interval-valued neutrosophic Pythagorean TOPSIS using the enhanced score function defined.
STEP 1: A problem is chosen with a set of choices and its respective criterions. The interval-valued neutrosophic Pythagorean values recorded are written in the form of a matrix called as the interval-valued neutrosophic Pythagorean decision matrix T_{ij} with interval-valued truth membership, false membership and indeterminacy membership values ranging from [0,1].

$$T_{ij} = \begin{bmatrix} t_{11}t_{12}t_{13} & . & . & . & t_{1n} \\ t_{21}t_{22}t_{23} & . & . & . & t_{2n} \\ t_{31}t_{32}t_{33} & . & . & . & t_{3n} \\ & & . & & \\ & & . & & \\ & & . & & \\ t_{m1}t_{m2}t_{m3} & . & . & . & t_{mn} \end{bmatrix}$$

STEP 2: The interval-valued neutrosophic Pythagorean values with its dependent components is reduced to the IVNP score matrix using the enhanced score function.

$$sc(M) = \frac{(\alpha^2 - \gamma^2 - \rho^2)\left(1 + \sqrt{1 - \alpha^2 - \gamma^2 - \rho^2}\right) + (\beta^2 - \delta^2 - \sigma^2)(1 + \sqrt{1 - \beta^2 - \delta^2 - \sigma^2})}{2}$$

STEP 3: The IVNP score matrix is normalized for favourable criteria and non-favourable criteria as follows:

For favourable criteria $\widetilde{T_{ij}} = \frac{T_{ij}}{\sqrt{\sum_{j=1}^{n} T_{ij}^2}}$

For non-favourable criteria $\widetilde{T_{ij}} = 1 - \frac{T_{ij}}{\sqrt{\sum_{j=1}^{n} T_{ij}^2}}$

STEP 4: From the normalized IVNP score matrix and with the aid of the weights assigned to each criterion, the weighted normalized IVNP matrix is framed by making use of the formula $W_{ij} = \widetilde{T_{ij}} * w_j$

STEP 5: The best ideal and worst ideal value for the attributes is chosen from the weighted normalized IVNP matrix as follows:

The best ideal V+ is the maximum value for the favourable attributes and minimum value for the non-favourable attributes, whereas to choose the worst ideal V-, we select the minimum value for the favourable attributes and maximum value for the non-favourable attributes.

STEP 6: Next, we proceed to calculate the Euclidean distance measure from the ideal best value to obtain the IVNP best ideal solution

$$s_i^+ = \left[\sum_{j=1}^{m} (T_{ij} - T_j^+)^2\right]^{0.5}$$

STEP 7: to calculate the Euclidean distance measure from the ideal worst value in order to compute the IVNP worst ideal solution

$$s_i^- = \left[\sum_{j=1}^{m} (T_{ij} - T_j^-)^2\right]^{0.5}$$

STEP 8: The IVNP performance score is calculated with the Euclidean distance measures from the best ideal and the worst ideal as follows:

$$P_i = \frac{s_i^+}{s_i^+ + s_i^-}$$

STEP 9: Based on the performance score obtained, the alternatives are ranked.

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VI. CASE STUDY

Assume a person is willing to invest his money in either of the four alternatives available which are car company, food production company, computer organization or in pharmaceutical production. The decision has to be made relying upon the risk (B_1), growth analysis (B_2) and environmental impact analysis (B_3). Let us assume the weights of the criteria be 0.35,0.25 and 0.40.

STEP 1: The interval-valued neutrosophic Pythagorean decision matrix for the above problem is given as

$$T_{ij} = \begin{bmatrix} [0.4,0.5],[0.2,0.3],[0.3,0.4][0.4,0.6],[0.3,0.4],[0.2,0.4][0.1,0.3],[0.2,0.4],[0.5,0.6] \\ [0.6,0.7],[0.1,0.3],[0.2,0.3][0.6,0.7],[0.3,0.5],[0.2,0.3][0.4,0.6],[0.1,0.2],[0.1,0.2] \\ [0.3,0.6],[0.2,0.5],[0.3,0.4][0.5,0.6],[0.3,0.5],[0.3,0.4][0.3,0.6],[0.1,0.2],[0.1,0.3] \\ [0.7,0.8],[0.3,0.4],[0.1,0.2][0.6,0.7],[0.2,0.3],[0.1,0.3][0.3,0.4],[0.2,0.3],[0.1,0.2] \end{bmatrix}$$

STEP 2: Using the enhanced score function, the interval-valued neutrosophic Pythagorean decision matrix is converted as the IVNP score matrix :

$$IVNP\ SCORE\ MATRIX: \begin{bmatrix} 0.0276 & 0.0516 & -0.6064 \\ 0.5181 & 0.3012 & 0.3782 \\ -0.0746 & 0.02467 & 0.2651 \\ 0.6278 & 0.5154 & 0.0662 \end{bmatrix}$$

STEP 3: Normalization of the IVNP score matrix for the favourable and non-favourable criteria are and hence the Normalized IVNP matrix is

$$\widetilde{T_{ij}} = \begin{bmatrix} 0.9662 & 0.0861 & -0.7925 \\ 0.3665 & 0.5022 & 0.4942 \\ 1.0912 & 0.0411 & 0.3465 \\ 0.2323 & 0.8594 & 0.0865 \end{bmatrix}$$

STEP 4: The Weighted Normalized IVNP matrix is obtained by using the weights allotted for the criteria which are 0.35,0.25,0.40.

$$\text{Weighted Normalized IVNP Matrix } W_{ij} = \begin{bmatrix} 0.3382 & 0.0215 & -0.3170 \\ 0.1283 & 0.1256 & 0.1977 \\ 0.0813 & 0.0103 & 0.1386 \\ 0.0813 & 0.2148 & 0.0346 \end{bmatrix}$$

STEP 5: From the weighted Normalized IVNP matrix, the best ideals and the worst ideals are chosen.

		B_1	B_2	B_3
BEST IDEAL	V+	0.0813	0.2148	0.1977
WORST IDEAL	V-	0.3382	0.0103	-0.3170

STEP 6: The Euclidean distance of the alternatives from the best ideal is calculated and the values of the IVNP best ideal solution are recorded as

ALTERNATIVES	S_i^+
A1	0.6068
A2	0.1008
A3	0.2129
A4	0.1630

STEP 7: In the same manner, we compute the Euclidean distance of the alternatives from the worst ideal value and the values of the IVNP worst ideal solution are

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ALTERNATIVES	S_i^-
A1	0.0112
A2	0.5676
A3	0.5230
A4	0.4811

STEP 8: The IVNP performance level is calculated using the Euclidean distances from the best ideal and the worst ideals.

ALTERNATIVES	P_i
A1	0.0181
A2	0.8490
A3	0.7106
A4	0.7468

STEP 9: The level of performance then leads us to grade and rank the alternatives at hand and they are ranked in their decreasing order.

ALTERNATIVES	P_i	RANK
A1	0.0181	4
A2	0.8490	1
A3	0.7106	3
A4	0.7468	2

Hence the ranking order is A2>A4>A3>A1

VII. CONCLUSION

The Interval-valued Neutrosophic Pythagorean TOPSIS has yielded us with the result that the decision maker can choose to invest his amount in a food production company A2, so that he gets a profit on his investing. This result obtained is compared with the existing methods and hence we arrive at a comparative analysis. On comparing with the existing results, the proposed IVNP-TOPSIS is in coincidence with the existing results hence validating it. Also, this proposed method is highly favourable and stable to compute the decision-making problems as it is performed in a Neutrosophic Pythagorean environment.

	A1	A2	A3	A4	RANK
Yager	-0.0993	0.2706	0.1266	0.0500	A2>A3>A4>A1
Garg 28	-0.6763	-0.4115	-0.5350	-0.5398	A2>A3>A4>A1
Peng &Yang	-0.0362	0.2992	0.1647	0.2232	A2>A4>A3>A1
Garg	0.0836	0.4589	0.1860	0.2212	A2>A4>A3>A1
Proposed IVNP-TOPSIS	0.0181	0.8490	0.7106	0.7468	A2>A4>A3>A1

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