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On Parameterized Time Neutrosophic Soft Set and Its Application

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Abstract. In his doctoral dissertation, Ayman A. Hazaymeh presented the idea of time-fuzzy soft set in 2013, which is an extension of fuzzy soft set[1]. In this work, we present the idea of the parameterized time neutrosophic soft set, which is an extension of the neutrosophic soft set, and examine some of its characteristics. Its fundamental operations, complement, union, intersection, "AND," and "OR," are also defined, and their characteristics are examined. We also provide a fictitious example of how this idea may be used in decision-making issues.

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1. General Introduction

The majority of problems in engineering, medical research, economics, and the environment are fraught with uncertainty. Molodtsov[2] introduced the notion of soft set theory as a tool in math for coping with such uncertainty. Following Molodtsov's work, [3], Maji et al.[4], and Maji et al. researched several soft set operations and applications. Also, Maji et al. [5] presented the notion of fuzzy soft set as a broader concept, as well as a combination of fuzzy set and soft set, and investigated its features. Roy and Maji [6] also applied this idea to handle decision-making challenges. The application of generalized fuzzy soft sets in decision-making problems and medical diagnosis problems is also introduced by them. Furthermore, in 2010, Çağman et al.[7] established the notion of fuzzy parameterized fuzzy soft set and its operations. In addition, the fpfs-aggregation operator is used to create the fpfs-decision-making technique, which allows for more efficient decision processes. The theory of neutrosophic sets was introduced by Smarandache [8] in

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1995 as a new mathematical tool for dealing with issues involving inconsistent, imprecise, and indeterminate data. Some topics in algebraic structures are extended by fuzzy soft sets, neutrosophic, or even plithogenic logical sets, as in the research [9], and there are also studies in fuzzy tapology and neutrosophic fuzzy topology. For more details about neutrosophic topology, see [10]. Additionally, researchers introduced using a neutrosophic fuzzy soft set to solve decision-making problems, like in [11], [12],[13] other researchers introduced topics in complex fuzzy as [14]. Enriching the state with knowledge about prior actions and events can help you distinguish between situations that might otherwise look identical, allowing you to make accurate judgments while also learning the proper options. Furthermore, knowledge of the past can eliminate the need for unrealistic sensors, such as knowing your exact location in a maze. Using historical information as part of the state representation provides us with important information to assist us in making better judgments in situations when temporal value is not taken into account, resulting in less accurate decision-making. If we want to take the views of more than one time (period), we must perform various operations such as union, intersection, etc. For a solution to this problem, we take a collection of time intervals, generalize it into what we call a time-fuzzy soft expert set (T-FSES) that is induced by [15], investigate some of its features, and apply this notion to a decision-making problem. It is critical to understand the history of the parameters under consideration in order to ensure the credibility of the information provided by specialists. The experts' previous experiences are gathered in the number of periods (years, months, etc.) in which they are involved in a certain decision-making circumstance, and by looking at the time component, individuals are more confident in the conclusion that they make. We must examine the influence of time on fuzzy soft set applications, not only for the present period, but also for the past and future periods (forecasting information). Generalized fuzzy soft expert sets were first proposed by Hazaymeh et al. [16], enabling the incorporation of several expert viewpoints in fuzzy decision-making settings. Fuzzy parameterized fuzzy soft expert sets [17] were subsequently developed, providing a deeper framework for complicated applications by combining the benefits of expert assessment under fuzziness and parameterization. The addition of temporal concerns furthered the development of these models. In order to further enhance the practical utility of soft computing approaches, Hazaymeh [18] introduced the time-effective fuzzy soft set, which highlights the significance of decision-making efficiency in time-sensitive scenarios. Alkhazaleh [19] added the parameterized time neutrosophic soft set to these advancements, offering a potent method for handling inconsistent and ambiguous data across time. In real-world situations where time and uncertainty are intricately entwined, this paradigm works very well. Furthermore, the partnership between Alkhazaleh and Hazaymeh resulted in the creation of N-valued refined neutrosophic soft sets [20], which provide a sophisticated method for managing intricate and multi-valued uncertainty in fields like decision analysis and medical diagnostics. When taken as a whole, these contributions mark a substantial improvement in the modeling and analysis of uncertainty in dynamic, multi-expert settings. Further development of these mathematical frameworks might lead to wider use in data analysis, intelligent systems, and decision support technologies. Neutosophic theory emerged as a potent expansion of fuzzy and intuitionistic fuzzy frameworks due to the difficulty of expressing uncertainty and indeterminacy in a variety of mathematical and real-world systems. Neutrosophic sets provide a more sophisticated solution to issues involving ambiguity and insufficient information by enabling the separate representation of truth, falsehood, and indeterminacy. In this regard, the inclusion of neutrosophic structures has greatly expanded fixed point theory in generalized metric spaces. In order to provide solutions to fractional differential equations that occur in the applied sciences, Bataihah et al. [21] developed fresh fixed point findings using a new form of distance space. Furthermore, by proving fixed point theorems in entire neutrosophic metric spaces—with a special emphasis on ψ-quasi contractions—Bataihah, Hazaymeh, Al-Qudah, and Al-Sharqi [21] advanced this topic. These findings not only advance our theoretical knowledge of neutrosophic spaces but also pave the way for nonlinear analysis and dynamical systems applications. Simultaneously, neutrosophic logic has become more popular in decision-making, particularly when there are several qualities and ambiguous preferences. Using potential single-valued neutrosophic Dombi-weighted aggregation operators, Al-Qudah et al. [21] presented a robust framework that allowed for more flexible and nuanced decision-making. In complex situations, these aggregation strategies facilitate well-informed decision-making by efficiently synthesizing imprecise and ambiguous information. Collectively, these papers highlight the growing contribution of neutrosophic mathematics to theoretical and practical problems, especially in fixed point theory and uncertain multi-criteria decision-making. Recent advances have contributed significantly to the refinement of such inequalities. In particular, Qawasmeh et al. [22] have presented further accurate numerical radius inequalities that improve upon existing results by providing tighter bounds under various operator conditions. Their work explores inequalities involving numerical radius and the norms of operator products and commutators, offering insights that are both theoretically enriching and practically applicable in matrix analysis and quantum mechanics. fuzzy soft set theory was introduced to better model scenarios involving imprecise information. This theory further enhances the ability to process uncertain data by incorporating the concepts of both fuzzy sets and soft sets [23].

introduction of neutrosophic graphs consider advancement is the provide a flexible mathematical tool for handling indeterminacy, especially in dynamic and complex environments. Recent studies have applied neutrosophic graph models to real-world problems such as earthquake response systems in Japan [24], and the identification of internet streaming services using the max product of complement operations in neutrosophic frameworks [25]. In parallel, fuzzy set extensions have also evolved significantly. The complex shadowed set theory enhances classical shadowed sets by incorporating complex-valued membership, allowing for the modeling of multidimensional uncertainty in decision-making scenarios [26]. Likewise, complex hesitant fuzzy graphs (CHFGs) represent an important generalization in fuzzy graph theory, effectively modeling situations where both hesitation and complex uncertainty are present [27].

Furthermore, to address even more nuanced aspects of uncertainty, the refined neutrosophic soft set theory has been proposed. This extension allows for the representation of truth, indeterminacy, and falsity in a more granular way, offering a more comprehensive framework for decision-making in ambiguous environments [28]. These developments have opened new avenues for applications in various fields such as decision support systems, pattern recognition, and data analysis. Recent research has also explored more sophisticated structures such as possibility interval-valued neutrosophic soft sets, which combine interval-valued and possibility-based neutrosophic frameworks. These have proven particularly effective in multi-criteria decision-making problems, where handling incomplete and inconsistent information is critical [29]. These advancements continue to open new avenues in applications such as decision support systems, data mining, and intelligent computing.Recently, various scholars have begun studying the properties and applications of time fuzzy soft set theory as in the research [30]. The following paper presents the idea of parameterized time neutrosophic soft set (P-TNSS), a generalization of the neutrosophic soft set, to improve decision-making in real situations. By incorporating historical information, we can disambiguate between identical situations, making correct decisions and learning from them. The paper also discusses the properties of P-TNSS, including complement, union, intersection, "AND," and "OR," and its application in decision-making problems.

2. Preliminary

The definitions and characteristics of neutrosophic soft set theory, time-fuzzy soft set theory, and neutrosophic soft set theory that are necessary for this study are reviewed in this section.

Definition 1. *[8] The definition of a neutrosophic set A on the discourse universe X is $A = \{< x; T_A(x); I_A(x); F_A(x) >; x \in X\}$ where T; I; $F : X \to]^{-}0; 1^{+}[$ and $^{-}0 \leqslant T_A(x) + I_A(x) + F_A(x) \leq 3^{+}$.*

Molodtsov provided the following definition of a soft set. Let E be a collection of parameters and U be a universe. The power set of U and $A \subseteq E$ is represented by $P(U)$.

Definition 2. *[2] A* soft set *over U, is a pair (F, A), where F is a mapping*

$$F : A \to P(U).$$

Stated differently, a parameterized family of subsets of the universe U is a soft set over U. For $\varepsilon \in A, F(\varepsilon)$ might be seen as a set of ε-approximate elements of the soft set (F, A).

Definition 3. *[31] Let E be a set of parameters and U be an initial universe set. Consider $A \subset E$. Let $P(U)$ indicates the set of all neutrosophic sets of U. The collection (F, A) is termed to be the soft neutrosophic set over U, where F is a mapping provided by $F : A \to P(U)$.*

Definition 4. *[31] Consider two NSSs over the common universe U: (F, A) and (G, B). (F, A) is claimed to be neutrosophic soft subset of (G, B) if $A \subset B$; and $T_F(e)(x) \leq T_G(e)(x)$; $I_F(e)(x) \leq I_G(e)(x)$; $F_F(e)(x) \geq F_G(e)(x)$; $\forall e \in A; x \in U$. We indicate it by $(F, A) \subseteq (G, B)$. (F, A) is claimed to be neutrosophic soft super set of (G, B) if (G, B) is a neutrosophic soft subset of (F, A). We indicate it by $(F, A) \supseteq (G, B)$.*

Definition 5. *[31] The complement of NSSs (F, A) indicated by $(F; A)^c$ and is indicated as $(F, A)^c = (F^c, \rceil A)$; where $F^c : \rceil A \rightarrow P(U)$ is a mapping provided by $F^c(\alpha)$ = neutrosophic soft complement with $T_{F^c(x)} = F_{F(x)}$, $I_{F^c(x)} = I_{F(x)}$ and $F_{F^c(x)} = T_{F(x)}$.*

Definition 6. *[31] Let (H, A) and (G, B) be two NSSs over the common universe U. Then, '$(H, A) \cup (G, B)$ denotes the union of (H, A) and (G, B), which is defined by $(H, A) \cup (G, B) = (K, C)$, where $C = A \cup B$ and the truth-membership, indeterminacy-membership and falsity-membership of (K, C) are as follows:*

$$T_K(e)(m) = T_H(e)(m); \quad \text{if } e \in A - B;$$

$$= T_G(e)(m); \quad \text{if } e \in B - A;$$

$$= max(T_H(e)(m); T_G(e)(m)); \quad \text{if } e \in A \cap B.$$

$$I_K(e)(m) = I_H(e)(m); \quad \text{if } e \in A - B;$$

$$= I_G(e)(m); \quad \text{if } e \in B - A;$$

$$= \frac{I_H(e)(m) + I_G(e)(m))}{2}; \quad \text{if } e \in A \cap B.$$

$$F_K(e)(m) = F_H(e)(m); \quad \text{if } e \in A - B;$$

$$= F_G(e)(m); \quad \text{if } e \in B - A;$$

$$= min(F_H(e)(m); F_G(e)(m)); \quad \text{if } e \in A \cap B.$$

Definition 7. *[31] Consider two NSSs over the common universe U: (H, A) and (G, B). Then, $(H, A) \cup (G, B)$ indicates the intersection of (H, A) and (G, B), which is defined by $(H, A) \cup (G, B) = (K, C)$, where $C = A \cup B$ and the truth-membership, indeterminacy-membership and falsity-membership of (K, C) are as follows:*

$$T_K(e)(m) = min(T_H(e)(m); T_G(e)(m));$$

$$I_K(e)(m) = \frac{I_H(e)(m) + I_G(e)(m))}{2} \text{ and}$$

$$F_K(e)(m) = min(F_H(e)(m); F_G(e)(m)); \quad \forall e \in C.$$

Definition 8. *[31] Let (H, A) and (G, B) be two NSSs over the common universe U. Then the 'AND' operation on them is indicated by '$(H, A) \bigvee (G, B)$' and is defined by $(H, A) \bigvee (G, B) = (K, A \times B)$, where the truth-membership, indeterminacy-membership and falsity-membership of $(K, A \times B)$ are as follows:*

$$T_K(\alpha, \beta)(m) = min(T_H(\alpha)(m); T_G(\beta)(m));$$

$I_K(\alpha, \beta)(m) = \dfrac{I_H(\alpha)(m) + I_G(\beta)(m))}{2}$ *and*

$F_K(\alpha, \beta)(m) = max(F_H(\alpha)(m); F_G(\beta)(m)); \quad \forall\alpha \in A, \forall\beta \in B.$

Definition 9. *[31] Let (H, A) and (G, B) be two NSSs over the common universe U. Then the 'OR' operation on them is indicated by '$(H, A) \bigvee (G, B)$' and is defined by $(H, A) \bigvee (G, B) = (O, A \times B)$, where the truth-membership, indeterminacy-membership and falsity-membership of $(O, A \times B)$ are as follows:*

$T_O(\alpha, \beta)(m) = max(T_H(\alpha)(m); T_G(\beta)(m));$

$I_O(\alpha, \beta)(m) = \dfrac{I_H(\alpha)(m) + I_G(\beta)(m))}{2}$ *and*

$F_O(\alpha, \beta)(m) = min(F_H(\alpha)(m); F_G(\beta)(m)); \quad \forall\alpha \in A, \forall\beta \in B.$

Definition 10. *[32]. Let U be an initial universe, E the set of all parameters and X a fuzzy set over E with membership function*

$$\mu_X : E \to [0, 1],$$

and let γ_X be a fuzzy set over U for all $x \in E$. Then an fpfs-set Γ_X over U is a set defined by a function $\gamma_X(x)$ representing a mapping $\gamma_X : E \to F(U)$ such that

$$\gamma_X(x) = \emptyset \text{ if } \mu_X(x) = 0.$$

Here, γ_X is called a fuzzy approximate function of the fpfs-set Γ_X, and the value $\gamma_X(x)$ is a set called x-element of the fpfs-set for all $x \in E$. Thus, an fpfs-set Γ_X over U can be represented by the set of ordered pairs

$$\Gamma_X = \{(\mu_X(x)/x, \gamma_X(x)) : x \in E,\ \gamma_X(x) \in F(U), \mu_X(x) \in [0, 1]\}.$$

Definition 11. *[33] Let U be an initial universal set and let E be a set of parameters. Let I^U indicate the power set of all fuzzy subsets of U, let $A \subseteq E$ and T be a time period where $T = \{t_1, t_2, ..., t_n\}$. A collection of pairs $(F, E)_t \, \forall\, t \in T$ is called a* time-fuzzy soft set $\{T - FSS\}$ *over U where F is a mapping provided by*

$$F_t : A \to I^U.$$

Definition 12. *Let U be an initial universal set and let E be a set of parameters. Let N^U indicate the power set of all neutrosophic subsets of U, let $A \subseteq E$ and T be a time period where $T = \{t_1, t_2, ..., t_n\}$. A collection of pairs $(F, E)_t^N \, \forall\, t \in T$ is called a* parameterized time neutrosophic soft set $\{P - TNSSs\}$ *over U where F is a mapping provided by*

$$F_t : A \to N^U.$$

3. Parameterized time neutrosophic soft set (PP-TNSS)

This section provides of the definition of a parameterized time neutrosophic soft set (PP-TNSS) and give its basic properties.

Definition 13. *Consider U as the initial universal set and E as a collection of parameters. The factors represented by $E = \mu_{e_1}/e_1, \mu_{e_2}/e_2, ..., \mu_{e_n}/e_n$, are weighted according to the relevance levels of the parameters. Let N^U represent the power set of all neutrosophic subsets of U, let $A \subseteq E$, and let T be a time period such that $T = \{t_1, t_2, ..., t_n\}$,. A collection of pairs $(F, E)_t^N \, \forall t \in T$ is referred to as a parameterized* parameterized time neutrosophic soft set $\{P - TNSSs\}$ *over U, where F is a mapping provided by*

$$F_t : A \to N^U.$$

.

Example 1. *Let $U = \{u_1, u_2, u_3\}$ be a collection of universes, $E = \left\{\frac{e_1}{0.5}, \frac{e_2}{0.7}, \frac{e_3}{0.2}\right\}$ a set of parameters and $T = \{t_1, t_2, t_3,\}$ be a time period. Define a function*

$$F_t : A \to N^U.$$

as follows:

$$F_1\left(\tfrac{e_1}{0.5}\right) = \left\{\frac{{u_1}^{t_1}}{\langle 0.5; 0.2; 0.4\rangle}, \frac{{u_2}^{t_1}}{\langle 0.3; 0.1; 0.5\rangle}, \frac{{u_3}^{t_1}}{\langle 0.4; 0.2; 0.3\rangle}\right\},$$

$$F_1\left(\tfrac{e_2}{0.7}\right) = \left\{\frac{{u_1}^{t_1}}{\langle 0.7; 0.1; 0.2\rangle}, \frac{{u_2}^{t_1}}{\langle 0.6; 0.4; 0.2\rangle}, \frac{{u_3}^{t_1}}{\langle 0.2; 0.2; 0.6\rangle}\right\},$$

$$F_1\left(\tfrac{e_3}{0.2}\right) = \left\{\frac{{u_1}^{t_1}}{\langle 0.8; 0.2; 0.1\rangle}, \frac{{u_2}^{t_1}}{\langle 0.6; 0.4; 0.1\rangle}, \frac{{u_3}^{t_1}}{\langle 0.3; 0.3; 0.5\rangle}\right\},$$

$$F_2\left(\tfrac{e_1}{0.5}\right) = \left\{\frac{{u_1}^{t_2}}{\langle 0.7; 0.2; 0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}\right\},$$

$$F_2\left(\tfrac{e_2}{0.7}\right) = \left\{\frac{{u_1}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}\right\},$$

$$F_2\left(\tfrac{e_3}{0.2}\right) = \left\{\frac{{u_1}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}\right\},$$

$$F_3\left(\tfrac{e_1}{0.5}\right) = \left\{\frac{{u_1}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_2}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_3}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}\right\},$$

$$F_3\left(\tfrac{e_2}{0.7}\right) = \left\{\frac{{u_1}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_2}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_3}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}\right\},$$

$$F_3\left(\tfrac{e_3}{0.2}\right)=\left\{\frac{{u_1}^{t_3}}{\langle 0.4;0.2;0.3\rangle},\frac{{u_2}^{t_3}}{\langle 0.4;0.2;0.3\rangle},\frac{{u_3}^{t_3}}{\langle 0.4;0.2;0.3\rangle}\right\}.$$

The parameterized time neutrosophic soft sets $(F,E)_t^N$ may then be seen to comprise the collections of approximations shown below:

$$\begin{aligned}(F,E)_t^N=\Bigg\{&\left(\tfrac{e_1}{0.5},\left\{\frac{{u_1}^{t_1}}{\langle 0.5;0.2;0.4\rangle},\frac{{u_2}^{t_1}}{\langle 0.3;0.1;0.5\rangle},\frac{{u_3}^{t_1}}{\langle 0.4;0.2;0.3\rangle}\right\}\right),\\
&\left(\tfrac{e_2}{0.7},\left\{\frac{{u_1}^{t_1}}{\langle 0.7;0.1;0.2\rangle},\frac{{u_2}^{t_1}}{\langle 0.6;0.4;0.2\rangle},\frac{{u_3}^{t_1}}{\langle 0.2;0.2;0.6\rangle}\right\}\right),\\
&\left(\tfrac{e_3}{0.2},\left\{\frac{{u_1}^{t_1}}{\langle 0.8;0.2;0.1\rangle},\frac{{u_2}^{t_1}}{\langle 0.6;0.4;0.1\rangle},\frac{{u_3}^{t_1}}{\langle 0.3;0.3;0.5\rangle}\right\}\right),\\
&\left(\tfrac{e_1}{0.5},\left\{\frac{{u_1}^{t_2}}{\langle 0.7;0.2;0.3\rangle},\frac{{u_2}^{t_2}}{\langle 0.4;0.2;0.3\rangle},\frac{{u_3}^{t_2}}{\langle 0.4;0.2;0.3\rangle}\right\}\right),\\
&\left(\tfrac{e_2}{0.7},\left\{\frac{{u_1}^{t_2}}{\langle 0.4;0.2;0.3\rangle},\frac{{u_2}^{t_2}}{\langle 0.4;0.2;0.3\rangle},\frac{{u_3}^{t_2}}{\langle 0.4;0.2;0.3\rangle}\right\}\right),\\
&\left(\tfrac{e_3}{0.2},\left\{\frac{{u_1}^{t_2}}{\langle 0.5;0.3;0.6\rangle},\frac{{u_2}^{t_2}}{\langle 0.3;0.4;0.6\rangle},\frac{{u_3}^{t_2}}{\langle 0.1;0.3;0.5\rangle}\right\}\right),\\
&\left(\tfrac{e_1}{0.5},\left\{\frac{{u_1}^{t_3}}{\langle 0.7;0.1;0.1\rangle},\frac{{u_2}^{t_3}}{\langle 0.8;0.2;0.1\rangle},\frac{{u_3}^{t_3}}{\langle 0.7;0.1;0.3\rangle}\right\}\right),\\
&\left(\tfrac{e_2}{0.7},\left\{\frac{{u_1}^{t_3}}{\langle 0.1;0.5;0.5\rangle},\frac{{u_2}^{t_3}}{\langle 0.5;0.3;0.2\rangle},\frac{{u_3}^{t_3}}{\langle 0.4;0.2;0.3\rangle}\right\}\right),\\
&\left(\tfrac{e_3}{0.2},\left\{\frac{{u_1}^{t_3}}{\langle 0.9;0.4;0.1\rangle},\frac{{u_2}^{t_3}}{\langle 0.7;0.3;0.1\rangle},\frac{{u_3}^{t_3}}{\langle 0.5;0.5;0.1\rangle}\right\}\right)\Bigg\}.\end{aligned}$$

Definition 14. *For two P-TNSSs $(F,A)_t^N$ and $(G,B)_t^N$ over U, $(F,A)_t^N$ is called a P-TNSSs subset of $(G,B)_t^N$ if*

(i) $B\subseteq A$,

(ii) $\forall t\in T,\epsilon\in B$, $G_t(\epsilon)$ *is neutrosophic soft subset of* $F_t(\epsilon)$.

Definition 15. *Two P-TNSSs $(F,A)_t^N$ and $(G,B)_t^N$ on U, are said to be* equal *if*

$(F,A)_t^N$ is a P-TNSSs subset of $(G,A)_t^N$ and $(G,A)_t^N$ is a P-TNSSs subset of $(F,A)_t^N$.

Example 2. *Think About the Example 1 and suppose that the*

$$(F,E)_t^N = \left\{ \left(\tfrac{e_1}{0.5}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.5; 0.2; 0.4\rangle}, \frac{{u_2}^{t_1}}{\langle 0.3; 0.1; 0.5\rangle}, \frac{{u_3}^{t_1}}{\langle 0.4; 0.2; 0.3\rangle} \right\} \right), \left(\tfrac{e_2}{0.7}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.7; 0.1; 0.2\rangle}, \frac{{u_2}^{t_1}}{\langle 0.6; 0.4; 0.2\rangle}, \frac{{u_3}^{t_1}}{\langle 0.2; 0.2; 0.6\rangle} \right\} \right), \left(\tfrac{e_2}{0.7}, \left\{ \frac{{u_1}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle} \right\} \right), \left(\tfrac{e_3}{0.2}, \left\{ \frac{{u_1}^{t_2}}{\langle 0.5; 0.3; 0.6\rangle}, \frac{{u_2}^{t_2}}{\langle 0.3; 0.4; 0.6\rangle}, \frac{{u_3}^{t_2}}{\langle 0.1; 0.3; 0.5\rangle} \right\} \right), \left(\tfrac{e_1}{0.5}, \left\{ \frac{{u_1}^{t_3}}{\langle 0.7; 0.1; 0.1\rangle}, \frac{{u_2}^{t_3}}{\langle 0.8; 0.2; 0.1\rangle}, \frac{{u_3}^{t_3}}{\langle 0.7; 0.1; 0.3\rangle} \right\} \right), \left(\tfrac{e_3}{0.2}, \left\{ \frac{{u_1}^{t_3}}{\langle 0.9; 0.4; 0.1\rangle}, \frac{{u_2}^{t_3}}{\langle 0.7; 0.3; 0.1\rangle}, \frac{{u_3}^{t_3}}{\langle 0.5; 0.5; 0.1\rangle} \right\} \right) \right\}.$$

$$(G,E)_t^N = \left\{ \left(\tfrac{e_2}{0.4}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.5; 0.1; 0.4\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4; 0.2; 0.4\rangle}, \frac{{u_3}^{t_1}}{\langle 0.1; 0.1; 0.8\rangle} \right\} \right), \left(\tfrac{e_3}{0.1}, \left\{ \frac{{u_1}^{t_2}}{\langle 0.2; 0.1; 0.8\rangle}, \frac{{u_2}^{t_2}}{\langle 0.1; 0.1; 0.6\rangle}, \frac{{u_3}^{t_2}}{\langle 0.2; 0.1; 0.7\rangle} \right\} \right), \left(\tfrac{e_1}{0.3}, \left\{ \frac{{u_1}^{t_3}}{\langle 0.3; 0.1; 0.5\rangle}, \frac{{u_2}^{t_3}}{\langle 0.2; 0.2; 0.7\rangle}, \frac{{u_3}^{t_3}}{\langle 0.2; 0.1; 0.5\rangle} \right\} \right) \right\}.$$

Therefore $(G,E)_t^N \subseteq (F,E)_t^N$.

Definition 16. *A parameterized time neutrosophic soft set $(F,A)_t^N$ over U is claimed to be semi-null P-TNSSs indicated by $T_{\sim}\phi$, if $\forall t \in T$, $F_t(e) = \phi$ for at least one e.*

Definition 17. *A parameterized time neutrosophic soft set $(F,A)_t^N$ over U is claimed to be null P-TNSSs indicated by T_ϕ, if $\forall t \in T$, $F_t(e) = \phi$ $\forall e$.*

Definition 18. *A parameterized time neutrosophic soft set $(F,A)_t^N$ over U is claimed to be semi-absolute P-TNSSs indicated by $T_{\sim}A$, if $\forall t \in T$, $F_t(e) = \bar{1}$ for at least one e.*

Definition 19. *A parameterized time neutrosophic soft set $(F,A)_t^N$ over U is claimed to be absolute P-TNSSs indicated by T_A, if $\forall t \in T$, $F_t(e) = \bar{1}$ $\forall e$.*

Example 3. *Consider Example 1. Let*

$$
\begin{aligned}
(F,E)_t^N = \Bigg\{ & \left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right), \\
& \left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right), \\
& \left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right), \\
& \left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_2}}{\langle 0.7;0.2;0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4;0.2;0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.4;0.2;0.3\rangle}\right\}\right), \\
& \left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_2}}{\langle 0.4;0.2;0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4;0.2;0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.4;0.2;0.3\rangle}\right\}\right), \\
& \left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_2}}{\langle 0.5;0.3;0.6\rangle}, \frac{{u_2}^{t_2}}{\langle 0.3;0.4;0.6\rangle}, \frac{{u_3}^{t_2}}{\langle 0.1;0.3;0.5\rangle}\right\}\right), \\
& \left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_3}}{\langle 0.7;0.1;0.1\rangle}, \frac{{u_2}^{t_3}}{\langle 0.8;0.2;0.1\rangle}, \frac{{u_3}^{t_3}}{\langle 0.7;0.1;0.3\rangle}\right\}\right), \\
& \left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_3}}{\langle 0.1;0.5;0.5\rangle}, \frac{{u_2}^{t_3}}{\langle 0.5;0.3;0.2\rangle}, \frac{{u_3}^{t_3}}{\langle 0.4;0.2;0.3\rangle}\right\}\right), \\
& \left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_3}}{\langle 0.9;0.4;0.1\rangle}, \frac{{u_2}^{t_3}}{\langle 0.7;0.3;0.1\rangle}, \frac{{u_3}^{t_3}}{\langle 0.5;0.5;0.1\rangle}\right\}\right) \Bigg\}.
\end{aligned}
$$

Then $(F,E)_t^N = T_{\sim}\phi$.

Let

$$
\begin{aligned}
(F,E)_t^N = \Bigg\{ & \left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right), \\
& \left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right), \\
& \left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right), \\
& \left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right),
\end{aligned}
$$

$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right),$$

$$\left(\frac{e_3}{0.2}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right),$$

$$\left(\frac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right),$$

$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right),$$

$$\left(\frac{e_3}{0.2}, \left\{\frac{{u_1}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_2}^{t_1}}{\langle 0;0;0\rangle}, \frac{{u_3}^{t_1}}{\langle 0;0;0\rangle}\right\}\right)\Bigg\}.$$

Then $(F,E)_t^N = T_\phi$.

Let

$$(F,E)_t^N = \Bigg\{\left(\frac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 1;1;0\rangle}, \frac{{u_2}^{t_1}}{\langle 1;1;0\rangle}, \frac{{u_3}^{t_1}}{\langle 1;1;0\rangle}\right\}\right),$$

$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 1;1;0\rangle}, \frac{{u_2}^{t_1}}{\langle 1;1;0\rangle}, \frac{{u_3}^{t_1}}{\langle 1;1;0\rangle}\right\}\right),$$

$$\left(\frac{e_3}{0.2}, \left\{\frac{{u_1}^{t_1}}{\langle 1;1;0\rangle}, \frac{{u_2}^{t_1}}{\langle 1;1;0\rangle}, \frac{{u_3}^{t_1}}{\langle 1;1;0\rangle}\right\}\right),$$

$$\left(\frac{e_1}{0.5}, \left\{\frac{{u_1}^{t_2}}{\langle 0.7;0.2;0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4;0.2;0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.4;0.2;0.3\rangle}\right\}\right),$$

$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_2}}{\langle 0.4;0.2;0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4;0.2;0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.4;0.2;0.3\rangle}\right\}\right),$$

$$\left(\frac{e_3}{0.2}, \left\{\frac{{u_1}^{t_2}}{\langle 0.5;0.3;0.6\rangle}, \frac{{u_2}^{t_2}}{\langle 0.3;0.4;0.6\rangle}, \frac{{u_3}^{t_2}}{\langle 0.1;0.3;0.5\rangle}\right\}\right),$$

$$\left(\frac{e_1}{0.5}, \left\{\frac{{u_1}^{t_3}}{\langle 0.7;0.1;0.1\rangle}, \frac{{u_2}^{t_3}}{\langle 0.8;0.2;0.1\rangle}, \frac{{u_3}^{t_3}}{\langle 0.7;0.1;0.3\rangle}\right\}\right),$$

$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_3}}{\langle 0.1;0.5;0.5\rangle}, \frac{{u_2}^{t_3}}{\langle 0.5;0.3;0.2\rangle}, \frac{{u_3}^{t_3}}{\langle 0.4;0.2;0.3\rangle}\right\}\right),$$

$$\left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_3}}{\langle 0.9; 0.4; 0.1\rangle}, \frac{{u_2}^{t_3}}{\langle 0.7; 0.3; 0.1\rangle}, \frac{{u_3}^{t_3}}{\langle 0.5; 0.5; 0.1\rangle}\right\}\right)\Bigg\}.$$

Then $(F, A)_t^N = T_{\sim}A$.

Let

$$\begin{aligned}(F, E)_t^N = \Bigg\{ &\left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_1}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_1}}{\langle 1; 1; 0\rangle}\right\}\right),\\
&\left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_1}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_1}}{\langle 1; 1; 0\rangle}\right\}\right),\\
&\left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_1}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_1}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_1}}{\langle 1; 1; 0\rangle}\right\}\right),\\
&\left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_2}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_2}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_2}}{\langle 1; 1; 0\rangle}\right\}\right),\\
&\left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_2}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_2}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_2}}{\langle 1; 1; 0\rangle}\right\}\right),\\
&\left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_2}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_2}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_2}}{\langle 1; 1; 0\rangle}\right\}\right),\\
&\left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_3}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_3}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_3}}{\langle 1; 1; 0\rangle}\right\}\right),\\
&\left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_3}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_3}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_3}}{\langle 1; 1; 0\rangle}\right\}\right),\\
&\left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_3}}{\langle 1; 1; 0\rangle}, \frac{{u_2}^{t_3}}{\langle 1; 1; 0\rangle}, \frac{{u_3}^{t_3}}{\langle 1; 1; 0\rangle}\right\}\right)\Bigg\}.\end{aligned}$$

Then $(F, A)_t^N = T_A$.

4. Basic Operations

The definitions of the complement, union, and intersection of P-TNSS are presented in this section along with various instances and attributes that are derived.

4.1. Complement

Definition 20. *The* complement *of P-TNSSs* $(F,A)_t^N$ *is indicated by* $\widetilde{c}(F,A)_t$ $\forall t \in T$ *where* $\widetilde{c}$ *indicates a neutrosophic soft complement.*

Example 4. *Consider Example 1, we have*

$$\widetilde{c}(F,E)_t^N = \Bigg\{ \left(\frac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 0.4;0.2;0.5\rangle}, \frac{{u_2}^{t_1}}{\langle 0.5;0.1;0.3\rangle}, \frac{{u_3}^{t_1}}{\langle 0.3;0.2;0.4\rangle}\right\}\right),$$
$$\left(\frac{e_2}{0.3}, \left\{\frac{{u_1}^{t_1}}{\langle 0.2;0.1;0.7\rangle}, \frac{{u_2}^{t_1}}{\langle 0.2;0.4;0.6\rangle}, \frac{{u_3}^{t_1}}{\langle 0.6;0.2;0.2\rangle}\right\}\right),$$
$$\left(\frac{e_3}{0.8}, \left\{\frac{{u_1}^{t_1}}{\langle 0.1;0.2;0.8\rangle}, \frac{{u_2}^{t_1}}{\langle 0.1;0.4;0.6\rangle}, \frac{{u_3}^{t_1}}{\langle 0.5;0.3;0.3\rangle}\right\}\right),$$
$$\left(\frac{e_1}{0.5}, \left\{\frac{{u_1}^{t_2}}{\langle 0.3;0.2;0.7\rangle}, \frac{{u_2}^{t_2}}{\langle 0.3;0.2;0.4\rangle}, \frac{{u_3}^{t_2}}{\langle 0.3;0.2;0.4\rangle}\right\}\right),$$
$$\left(\frac{e_2}{0.3}, \left\{\frac{{u_1}^{t_2}}{\langle 0.3;0.2;0.4\rangle}, \frac{{u_2}^{t_2}}{\langle 0.3;0.2;0.4\rangle}, \frac{{u_3}^{t_2}}{\langle 0.3;0.2;0.4\rangle}\right\}\right),$$
$$\left(\frac{e_3}{0.8}, \left\{\frac{{u_1}^{t_2}}{\langle 0.6;0.3;0.5\rangle}, \frac{{u_2}^{t_2}}{\langle 0.6;0.4;0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.1;0.3;0.5\rangle}\right\}\right),$$
$$\left(\frac{e_1}{0.5}, \left\{\frac{{u_1}^{t_3}}{\langle 0.1;0.1;0.7\rangle}, \frac{{u_2}^{t_3}}{\langle 0.1;0.2;0.8\rangle}, \frac{{u_3}^{t_3}}{\langle 0.3;0.1;0.7\rangle}\right\}\right),$$
$$\left(\frac{e_2}{0.3}, \left\{\frac{{u_1}^{t_3}}{\langle 0.5;0.5;0.1\rangle}, \frac{{u_2}^{t_3}}{\langle 0.2;0.3;0.5\rangle}, \frac{{u_3}^{t_3}}{\langle 0.3;0.2;0.4\rangle}\right\}\right),$$
$$\left(\frac{e_3}{0.8}, \left\{\frac{{u_1}^{t_3}}{\langle 0.1;0.4;0.9\rangle}, \frac{{u_2}^{t_3}}{\langle 0.1;0.3;0.7\rangle}, \frac{{u_3}^{t_3}}{\langle 0.1;0.5;0.5\rangle}\right\}\right)\Bigg\}.$$

Proposition 1. *If* $(F,A)_t^N$ *is a P-TNSSs over* U, *and by using the neutrosophic complement we have:*

(i) $\widetilde{c}\left(\widetilde{c}(F,A)_t^N\right) = (F,A)_t^N$,

(ii) $\widetilde{c}(T_\sim\phi) = (T_\sim A)$,

(iii) $\widetilde{c}(T_\phi) = (T_A)$,

(iv) $\widetilde{c}(T_\sim A) = (T_\sim\phi)$,

(v) $\widetilde{c}(T_A) = (T_\phi)$.

Proof. The Definition provides a clear proof. 20.

4.2. Union

Definition 21. *The* union *of two P-TNSSs* $(F,A)_t^N$ *and* $(G,B)_t^N$ *over* U, *is the P-TNSSs* $(H,C)_t^N$, *indicated by* $(F,A)_t^N \,\tilde{\cup}\, (G,B)_t^N$, *such that* $C = A \cup B \subset E$ *and is defined as follows*

$$H_t^N(\epsilon) = \begin{cases} F_t(\epsilon), & if\, \epsilon \in A - B, \\ G_t(\epsilon), & if\, \epsilon \in B - A, \\ F_t(\epsilon) \,\tilde{\cup}\, G_t(\epsilon), & if\, \epsilon \in A \cup B, \end{cases}$$

where $\tilde{\cup}$ *indicated the parameterized time neutrosophic soft union.*

Example 5. *Consider Example Think About the Example 1. Assume two parameterized time neutrosophic soft sets over* U, $(F,A)_t^N$ *and* $(G,B)_t^N$, *such that*

$$(F,A)_t^N = \left\{ \left(\tfrac{e_1}{0.5}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.1; 0.5; 0.6\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4; 0.3; 0.4\rangle}, \frac{{u_3}^{t_1}}{\langle 0.3; 0.3; 0.6\rangle} \right\} \right), \right.$$
$$\left(\tfrac{e_2}{0.7}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.7; 0.4; 0.3\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4; 0.5; 0.3\rangle}, \frac{{u_3}^{t_1}}{\langle 0.4; 0.4; 0.4\rangle} \right\} \right),$$
$$\left(\tfrac{e_2}{0.7}, \left\{ \frac{{u_1}^{t_2}}{\langle 0.1; 0.5; 0.7\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.6; 0.2\rangle}, \frac{{u_3}^{t_2}}{\langle 0.8; 0.2; 0.1\rangle} \right\} \right),$$
$$\left. \left(\tfrac{e_3}{0.5}, \left\{ \frac{{u_1}^{t_3}}{\langle 0.5; 0.2; 0.4\rangle}, \frac{{u_2}^{t_3}}{\langle 0.3; 0.3; 0.6\rangle}, \frac{{u_3}^{t_3}}{\langle 0.1; 0.2; 0.9\rangle} \right\} \right) \right\}.$$
$$(G,B)_t = \left\{ \left(\tfrac{e_1}{0.5}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.4; 0.3; 0.6\rangle}, \frac{{u_2}^{t_1}}{\langle 0.1; 0.7; 0.6\rangle}, \frac{{u_3}^{t_1}}{\langle 0.5; 0.4; 0.4\rangle} \right\} \right), \right.$$
$$\left(\tfrac{e_3}{0.2}, \left\{ \frac{{u_1}^{t_2}}{\langle 0.6; 0.2; 0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.7; 0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.2; 0.5; 0.7\rangle} \right\} \right),$$
$$\left. \left(\tfrac{e_3}{0.2}, \left\{ \frac{{u_1}^{t_3}}{\langle 0.7; 0.5; 0.2\rangle}, \frac{{u_2}^{t_3}}{\langle 0.1; 0.5; 0.8\rangle}, \frac{{u_3}^{t_3}}{\langle 0.9; 0.5; 0.1\rangle} \right\} \right) \right\}.$$

We can easily confirm that $(F,A)_t^N \,\tilde{\cup}\, (G,B)\, byemployingneutrosophicunion.where_t^N = (H,C)_t^N$

$$(H,C)_t^N = \left\{ \left(\tfrac{e_1}{0.5}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.4; 0.4; 0.6\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4; 0.5; 0.4\rangle}, \frac{{u_3}^{t_1}}{\langle 0.5; 0.35; 0.4\rangle} \right\} \right), \right.$$

$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 0.7; 0.4; 0.3\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4; 0.5; 0.3\rangle}, \frac{{u_3}^{t_1}}{\langle 0.4; 0.4; 0.4\rangle}\right\}\right),$$
$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_2}}{\langle 0.1; 0.5; 0.7\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.6; 0.2\rangle}, \frac{{u_3}^{t_2}}{\langle 0.8; 0.2; 0.1\rangle}\right\}\right),$$
$$\left(\frac{e_3}{0.2}, \left\{\frac{{u_1}^{t_2}}{\langle 0.6; 0.2; 0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.7; 0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.2; 0.5; 0.7\rangle}\right\}\right),$$
$$\left(\frac{e_3}{0.5}, \left\{\frac{{u_1}^{t_3}}{\langle 0.7; 0.35; 0.2\rangle}, \frac{{u_2}^{t_3}}{\langle 0.3; 0.4; 0.6\rangle}, \frac{{u_3}^{t_3}}{\langle 0.9; 0.35; 0.1\rangle}\right\}\right)\Bigg\}.$$

Proposition 2. *If $(F, A)_t^N$, $(G, B)_t^N$ and $(H, C)_t^N$ are three T-FSSs over U, then*

(i) $(F, A)_t^N \,\tilde{\cup}\, ((G, B)_t^N \,\tilde{\cup}\, (H, C)_t^N) = ((F, A)_t^N \,\tilde{\cup}\, (G, B))_t^N \,\tilde{\cup}\, (H, C)_t^N$,

(ii) $(F, A)_t^N \,\tilde{\cup}\, (F, A)_t^N = (F, A)_t^N$.

Proof. The Definition provides a clear proof. 5.

4.3. Intersection

Definition 22. *The* intersection *of two P-TNSSs $(F, A)_t^N$ and $(G, B)_t^N$ over U, is the P-TNSSs $(H, C)_t^N$, indicated by $(F, A)_t^N \,\tilde{\cap}\, (G, B)_t^N$, such that $C = A \cup B \subset E$ and is defined as follows*

$$H_t(\epsilon) = \begin{cases} F_t(\epsilon), & if\, \epsilon \in A - B, \\ G_t(\epsilon), & if\, \epsilon \in B - A, \\ F_t(\epsilon) \,\tilde{\cap}\, G_t(\epsilon), & if\, \epsilon \in A \cap B, \end{cases}$$

where the parameterized time neutrosophic soft intersection was denoted by $\tilde{\cap}$.

Example 6. *Consider Example Think About the Example 5. It is simple to confirm that $(F, A)_t^N \,\tilde{\cap}\, (G, B)\, utilizing the fundamental neutrosophic intersection. ((H, C)_t^N = ...{}_t^N$ where*

$$(H, C)_t^N = \Bigg\{\left(\frac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 0.1; 0.4; 0.6\rangle}, \frac{{u_2}^{t_1}}{\langle 0.1; 0.5; 0.6\rangle}, \frac{{u_3}^{t_1}}{\langle 0.3; 0.35; 0.6\rangle}\right\}\right),$$
$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 0.7; 0.4; 0.3\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4; 0.5; 0.3\rangle}, \frac{{u_3}^{t_1}}{\langle 0.4; 0.4; 0.4\rangle}\right\}\right),$$
$$\left(\frac{e_2}{0.7}, \left\{\frac{{u_1}^{t_2}}{\langle 0.1; 0.5; 0.7\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4; 0.6; 0.2\rangle}, \frac{{u_3}^{t_2}}{\langle 0.8; 0.2; 0.1\rangle}\right\}\right),$$

$$\left(\frac{e_3}{0.2}, \left\{\frac{u_1{}^{t_2}}{\langle 0.6; 0.2; 0.3\rangle}, \frac{u_2{}^{t_2}}{\langle 0.4; 0.7; 0.3\rangle}, \frac{u_3{}^{t_2}}{\langle 0.2; 0.5; 0.7\rangle}\right\}\right),$$
$$\left(\frac{e_3}{0.5}, \left\{\frac{u_1{}^{t_3}}{\langle 0.5; 0.35; 0.4\rangle}, \frac{u_2{}^{t_3}}{\langle 0.1; 0.4; 0.8\rangle}, \frac{u_3{}^{t_3}}{\langle 0.1; 0.35; 0.9\rangle}\right\}\right)\Bigg\}.$$

Proposition 3. *If $(F,A)_t^N$, $(G,B)_t^N$ and $(H,C)_t^N$ are three P-TNSSs over U, then*

(i) $(F,A)_t^N \,\tilde{\cap}\, ((G,B)_t^N \,\tilde{\cap}\, (H,C_t^N) = ((F,A)_t^N \,\tilde{\cap}\, (G,B))_t^N \,\tilde{\cap}\, (H,C)_t^N$,

(ii) $(F,A)_t^N \,\tilde{\cap}\, (F,A)_t^N = (F,A)_t^N$.

Proof. The Definition provides a clear proof. 22.

Proposition 4. *If $(F,A)_t^N$, $(G,B)_t^N$ and $(H,C)_t^N$ are three P-TNSSs over U, then*

(i) $(F,A)_t^N \,\tilde{\cup} \left((G,B)_t^N \,\tilde{\cap}\, (H,C)_t^N\right) = \left((F,A)_t^N \,\tilde{\cup}\, (G,B)_t^N\right) \tilde{\cap} \left((F,A)_t^N \,\tilde{\cup}\, (H,C)_t^N\right)$,

(ii) $(F,A)_t^N \,\tilde{\cap} \left((G,B)_t^N \,\tilde{\cup}\, (H,C)_t^N\right) = \left((F,A)_t^N \,\tilde{\cap}\, (G,B)_t^N\right) \tilde{\cup} \left((F,A)_t^N \,\tilde{\cap}\, (H,C)_t^N\right)$.

Proof. The proof is straightforward from Definitions 22 and 5.

Proposition 5. *If $(F,A)_t^N$ and $(G,B)_t^N$ are two P-TNSSs over U, then*

(i) $\left((F,A)_t^N \,\tilde{\cup}\, (G,B)_t^N\right)^c = ((F,A)_t^N)^c \tilde{\cap}\, ((G,B)_t^N)^c$,

(ii) $\left((F,A)_t^N \,\tilde{\cap}\, (G,B)_t^N\right)^c = ((F,A)_t^N)^C \tilde{\cup}\, ((G,B)_t^N)^C$.

Proof. The proof is straightforward from Definitions 22 and 5.

5. AND and OR Operations

The definitions, properties, and examples of AND and OR operations for P-TNSS are presented in this section.

Definition 23. *If $(F,A)_t^N$ and $(G,B)_t^N$ are two P-TNSSs over U then "$(F,A)_t^N$ AND $(G,B)_t^N$" indicated by $(F,A)_t^N \wedge (G,B)_t^N$, is defined by*

$$(F,A)_t^N \wedge (G,B)_t = (H, A \times B)_t$$

such that $H(\alpha,\beta)_t^N = F(\alpha)_t \widetilde{\bigcap} G(\beta)_t^N, \forall (\alpha,\beta) \in A \times B$, where $\widetilde{\bigcap}$ is parameterized time neutrosophic soft intersection.

Example 7. *Think About the Example 1. Let $(F,A)_t^N$ and $(G,B)_t^N$ are two P-TNSSs over U such that*

$$(F,A)^N_t = \left\{ \left(\tfrac{e_1}{0.5}, \left\{\frac{{u_1}^{t_1}}{\langle 0.1;0.5;0.6\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4;0.3;0.4\rangle}, \frac{{u_3}^{t_1}}{\langle 0.3;0.3;0.6\rangle}\right\}\right),\right.$$

$$\left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_1}}{\langle 0.7;0.4;0.3\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4;0.5;0.3\rangle}, \frac{{u_3}^{t_1}}{\langle 0.4;0.4;0.4\rangle}\right\}\right),$$

$$\left(\tfrac{e_2}{0.7}, \left\{\frac{{u_1}^{t_2}}{\langle 0.1;0.5;0.7\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4;0.6;0.2\rangle}, \frac{{u_3}^{t_2}}{\langle 0.8;0.2;0.1\rangle}\right\}\right),$$

$$\left.\left(\tfrac{e_3}{0.8}, \left\{\frac{{u_1}^{t_3}}{\langle 0.5;0.2;0.4\rangle}, \frac{{u_2}^{t_3}}{\langle 0.3;0.3;0.6\rangle}, \frac{{u_3}^{t_3}}{\langle 0.1;0.2;0.9\rangle}\right\}\right)\right\}.$$

$$(G,B)_t = \left\{ \left(\tfrac{e_1}{0.4}, \left\{\frac{{u_1}^{t_1}}{\langle 0.4;0.3;0.6\rangle}, \frac{{u_2}^{t_1}}{\langle 0.1;0.7;0.6\rangle}, \frac{{u_3}^{t_1}}{\langle 0.5;0.4;0.4\rangle}\right\}\right),\right.$$

$$\left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_2}}{\langle 0.6;0.2;0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.4;0.7;0.3\rangle}, \frac{{u_3}^{t_2}}{\langle 0.2;0.5;0.7\rangle}\right\}\right),$$

$$\left.\left(\tfrac{e_3}{0.2}, \left\{\frac{{u_1}^{t_3}}{\langle 0.7;0.5;0.2\rangle}, \frac{{u_2}^{t_3}}{\langle 0.1;0.5;0.8\rangle}, \frac{{u_3}^{t_3}}{\langle 0.9;0.5;0.1\rangle}\right\}\right)\right\}.$$

Then it's simple to confirm that $(F,A)^N_t \wedge (G,B)^N_t = (H, A\times B)^N_t$ *where:*

$$(H, A\times B)^N_t = \left\{ \left(\frac{0.4}{(e_1,e_1)}\right), \left\{\frac{{u_1}^{t_{1,1}}}{\langle 0.4;0.4;0.6\rangle}, \frac{{u_2}^{t_{1,1}}}{\langle 0.4;0.5;0.4\rangle}, \frac{{u_3}^{t_{1,1}}}{\langle 0.5;0.35;0.4\rangle}\right\},\right.$$

$$\left(\frac{0.2}{(e_1,e_3)}\right), \left\{\frac{{u_1}^{t_{1,2}}}{\langle 0.6;0.35;0.3\rangle}, \frac{{u_2}^{t_{1,2}}}{\langle 0.4;0.5;0.3\rangle}, \frac{{u_3}^{t_{1,2}}}{\langle 0.3;0.4;0.4\rangle}\right\},$$

$$\left(\frac{0.2}{(e_1,e_3)}\right), \left\{\frac{{u_1}^{t_{1,3}}}{\langle 0.7;0.5;0.2\rangle}, \frac{{u_2}^{t_{1,3}}}{\langle 0.4;0.4;0.4\rangle}, \frac{{u_3}^{t_{1,3}}}{\langle 0.9;0.4;0.1\rangle}\right\},$$

$$\left(\frac{0.4}{(e_2,e_1)}\right), \left\{\frac{{u_1}^{t_{1,1}}}{\langle 0.7;0.35;0.3\rangle}, \frac{{u_2}^{t_{1,1}}}{\langle 0.4;0.6;0.3\rangle}, \frac{{u_3}^{t_{1,1}}}{\langle 0.5;0.4;0.4\rangle}\right\},$$

$$\left(\frac{0.2}{(e_2,e_3)}\right), \left\{\frac{{u_1}^{t_{1,2}}}{\langle 0.7;0.3;0.3\rangle}, \frac{{u_2}^{t_{1,2}}}{\langle 0.4;0.6;0.3\rangle}, \frac{{u_3}^{t_{1,2}}}{\langle 0.4;0.45;0.4\rangle}\right\},$$

$$\left(\frac{0.2}{(e_2,e_3)}\right), \left\{\frac{{u_1}^{t_{1,3}}}{\langle 0.7;0.45;0.2\rangle}, \frac{{u_2}^{t_{1,3}}}{\langle 0.4;0.5;0.3\rangle}, \frac{{u_3}^{t_{1,3}}}{\langle 0.9;0.45;0.1\rangle}\right\},$$

$$\left(\frac{0.4}{(e_2,e_1)}\right), \left\{\frac{{u_1}^{t_{2,1}}}{\langle 0.4;0.4;0.6\rangle}, \frac{{u_2}^{t_{2,1}}}{\langle 0.4;0.65;0.2\rangle}, \frac{{u_3}^{t_{2,1}}}{\langle 0.8;0.3;0.1\rangle}\right\},$$

$$\left(\frac{0.2}{(e_2,e_3)}\right), \left\{\frac{{u_1}^{t_{2,2}}}{\langle 0.6;0.35;0.3\rangle}, \frac{{u_2}^{t_{2,2}}}{\langle 0.4;0.65;0.2\rangle}, \frac{{u_3}^{t_{2,2}}}{\langle 0.8;0.35;0.1\rangle}\right\},$$

$$\left(\frac{0.2}{(e_2,e_3)}\right),\left\{\frac{{u_1}^{t_{2,3}}}{\langle 0.7;0.5;0.2\rangle},\frac{{u_2}^{t_{2,3}}}{\langle 0.4;0.55;0.2\rangle},\frac{{u_3}^{t_{2,3}}}{\langle 0.9;0.35;0.1\rangle}\right\},$$

$$\left(\frac{0.4}{(e_3,e_1)}\right),\left\{\frac{{u_1}^{t_{3,1}}}{\langle 0.5;0.25;0.4\rangle},\frac{{u_2}^{t_{3,1}}}{\langle 0.3;0.5;0.6\rangle},\frac{{u_3}^{t_{3,1}}}{\langle 0.5;0.3;0.4\rangle}\right\},$$

$$\left(\frac{0.2}{(e_3,e_3)}\right),\left\{\frac{{u_1}^{t_{3,2}}}{\langle 0.6;0.2;0.3\rangle},\frac{{u_2}^{t_{3,2}}}{\langle 0.4;0.5;0.3\rangle},\frac{{u_3}^{t_{3,2}}}{\langle 0.2;0.35;0.7\rangle}\right\},$$

$$\left(\frac{0.2}{(e_1,e_3)}\right),\left\{\frac{{u_1}^{t_{3,3}}}{\langle 0.7;0.35;0.2\rangle},\frac{{u_2}^{t_{3,3}}}{\langle 0.3;0.4;0.6\rangle},\frac{{u_3}^{t_{3,3}}}{\langle 0.9;0.35;0.1\rangle}\right\}\Bigg\}.$$

Definition 24. *If $(F,A)_t^N$ and $(G,B)_t^N$ are two P-TNSSs over U then "$(F,A)_t^N$ OR $(G,B)_t^N$" indicated by $(F,A)_t^N \vee (G,B)_t^N$, is defined by*

$$(F,A)_t^N \vee (G,B)_t^N = (O, A\times B)_t$$

such that $O(\alpha,\beta)_t^N = F(\alpha)_t \widetilde{\bigcup} G(\beta)_t, \forall (\alpha,\beta)\in A\times B$, where $\widetilde{\bigcup}$ is parameterized time neutrosophic soft union.

Example 8. *Think About the Example 7 we have U Then we can easily verify that $(F,A)_t^N \vee (G,B)_t^N = (O, A\times B)_t^N$ where:*

$$(O,A\times B)_t^N = \Bigg\{\left(\frac{0.5}{(e_1,e_1)},\left\{\frac{{u_1}^{t_{1,1}}}{\langle 0.1;0.4;0.6\rangle},\frac{{u_2}^{t_{1,1}}}{\langle 0.1;0.5;0.6\rangle},\frac{{u_3}^{t_{1,1}}}{\langle 0.3;0.35;0.6\rangle}\right\}\right),$$

$$\left(\frac{0.5}{(e_1,e_3)}\right),\left\{\frac{{u_1}^{t_{1,2}}}{\langle 0.1;0.35;0.6\rangle},\frac{{u_2}^{t_{1,2}}}{\langle 0.4;0.5;0.4\rangle},\frac{{u_3}^{t_{1,2}}}{\langle 0.2;0.4;0.7\rangle}\right\},$$

$$\left(\frac{0.5}{(e_1,e_3)}\right),\left\{\frac{{u_1}^{t_{1,3}}}{\langle 0.1;0.5;0.6\rangle},\frac{{u_2}^{t_{1,3}}}{\langle 0.1;0.4;0.8\rangle},\frac{{u_3}^{t_{1,3}}}{\langle 0.3;0.4;0.6\rangle}\right\},$$

$$\left(\frac{0.7}{(e_2,e_1)}\right),\left\{\frac{{u_1}^{t_{1,1}}}{\langle 0.4;0.35;0.6\rangle},\frac{{u_2}^{t_{1,1}}}{\langle 0.1;0.6;0.6\rangle},\frac{{u_3}^{t_{1,1}}}{\langle 0.4;0.4;0.4\rangle}\right\},$$

$$\left(\frac{0.7}{(e_2,e_3)}\right),\left\{\frac{{u_1}^{t_{1,2}}}{\langle 0.6;0.3;0.3\rangle},\frac{{u_2}^{t_{1,2}}}{\langle 0.4;0.6;0.3\rangle},\frac{{u_3}^{t_{1,2}}}{\langle 0.2;0.45;0.7\rangle}\right\},$$

$$\left(\frac{0.7}{(e_2,e_3)}\right),\left\{\frac{{u_1}^{t_{1,3}}}{\langle 0.7;0.45;0.3\rangle},\frac{{u_2}^{t_{1,3}}}{\langle 0.1;0.5;0.8\rangle},\frac{{u_3}^{t_{1,3}}}{\langle 0.8;0.45;0.1\rangle}\right\},$$

$$\left(\frac{0.7}{(e_2,e_1)}\right),\left\{\frac{{u_1}^{t_{2,1}}}{\langle 0.1;0.4;0.7\rangle},\frac{{u_2}^{t_{2,1}}}{\langle 0.1;0.65;0.6\rangle},\frac{{u_3}^{t_{2,1}}}{\langle 0.5;0.3;0.4\rangle}\right\},$$

$$\left(\frac{0.7}{(e_2,e_3)}\right),\left\{\frac{{u_1}^{t_{2,2}}}{\langle 0.1;0.35;0.7\rangle},\frac{{u_2}^{t_{2,2}}}{\langle 0.4;0.65;0.3\rangle},\frac{{u_3}^{t_{2,2}}}{\langle 0.2;0.35;0.7\rangle}\right\},$$

$$\left(\frac{0.7}{(e_2,e_3)}\right),\left\{\frac{{u_1}^{t_{2,3}}}{\langle 0.1;0.5;0.7\rangle},\frac{{u_2}^{t_{2,3}}}{\langle 0.1;0.55;0.8\rangle},\frac{{u_3}^{t_{2,3}}}{\langle 0.8;0.35;0.1\rangle}\right\},$$
$$\left(\frac{0.8}{(e_3,e_1)}\right),\left\{\frac{{u_1}^{t_{3,1}}}{\langle 0.4;0.25;0.6\rangle},\frac{{u_2}^{t_{3,1}}}{\langle 0.1;0.5;0.6\rangle},\frac{{u_3}^{t_{3,1}}}{\langle 0.1;0.3;0.9\rangle}\right\},$$
$$\left(\frac{0.8}{(e_3,e_3)}\right),\left\{\frac{{u_1}^{t_{3,2}}}{\langle 0.5;0.2;0.4\rangle},\frac{{u_2}^{t_{3,2}}}{\langle 0.3;0.5;0.6\rangle},\frac{{u_3}^{t_{3,2}}}{\langle 0.1;0.35;0.9\rangle}\right\},$$
$$\left(\frac{0.8}{(e_2,e_3)}\right),\left\{\frac{{u_1}^{t_{3,3}}}{\langle 0.5;0.35;0.4\rangle},\frac{{u_2}^{t_{3,3}}}{\langle 0.1;0.4;0.8\rangle},\frac{{u_3}^{t_{3,3}}}{\langle 0.2;0.35;0.7\rangle}\right\}\Bigg\}.$$

Proposition 6. *If* $(F,A)_t^N$ *and* $(G,B)_t^N$ *are two P-TNSSs over* U*, then*

(i) $\left((F,A)_t^N \wedge (G,B)_t^N\right)^c = ((F,A)_t^N)^c \vee ((G,B)_t^N)^c$

(ii) $\left((F,A)_t^N \vee (G,B)_t^N\right)^c = ((F,A)_t^N)^c \wedge ((G,B)_t^N)^c$

Proof. The proof is straightforward from Definitions 23, 24 and 20.

Proposition 7. *If* $(F,A)_t^N$, $(G,B)_t^N$ *and* $(H,C)_t^N$ *are three P-TNSSs over* U*, then*

(i) $(F,A)_t^N \wedge \left((G,B)_t^N \wedge (H,C)_t^N\right) = \left((F,A)_t^N \wedge (G,B)_t^N\right) \wedge (H,C)_t^N,$

(ii) $(F,A)_t^N \vee \left((G,B)_t^N \vee (H,C)_t^N\right) = \left((F,A)_t^N \vee (G,B)_t^N\right) \vee (H,C)_t^N,$

(iii) $(F,A)_t^N \vee \left((G,B)_t^N \wedge (H,C)_t^N\right) = \left((F,A)_t^N \vee (G,B)_t^N\right) \wedge \left((F,A)_t^N \vee (H,C)_t^N\right),$

(iv) $(F,A)_t^N \wedge \left((G,B)_t^N \vee (H,C)_t^N\right) = \left((F,A)_t^N \wedge (G,B)_t^N\right) \vee \left((F,A)_t^N \wedge (H,C)_t^N\right).$

Proof. The proof is straightforward from Definitions 23 and 24.

5.1. The applying of parameterized time neutrosophic soft skills to decision-making.

In this section, we present a theoretical application of the parameterized time neutrosophic soft set theory within a decision-making context, illustrating that this approach can be effectively utilized in various domains characterized by uncertainty. We propose the following algorithm for addressing decision-making challenges based on parameterized time neutrosophic soft sets. It is important to mention that we will refer to Maji's Algorithm using the abbreviation (MA).

Definition 25. *[31] matrix of comparisons. The object names $h_1; h_2; ..., h_n$ are used to identify the rows of this matrix, whereas the parameters $e_1; e_2; ..., e_m$ are used to identify the columns: $c_{ij} = a + b - c$ is used to compute the entries c_{ij}. where 'a' is the integer calculated as 'how many times $T_{h_i}(e_j)$ exceeds or equal to $T_{h_k}(e_j)$', for $h_i \neq h_k$, $\forall h_k \in U$, 'b'is the integer calculated as 'how many times $I_{h_i}(e_j)$ exceeds or equal to $I_{h_k}(e_j)$', for $h_i \neq h_k$, $\forall h_k \in U$, and 'c' is the integer 'how many times $F_{h_i}(e_j)$ exceeds or equal to $F_{h_k}(e_j)$', for $h_i \neq h_k$, $\forall h_k \in U$,.*

Definition 26. *[31] Score of an Object. The score of an object h_i is S_i and is calculated as $S_i = \sum_j c_{ij}$*

Example 9. *A restaurant chain is considering the establishment of a new branch in one of the city's suburbs and has sought the expertise of specialists to conduct an economic feasibility analysis of the chosen location. The experts employed specific criteria to arrive at their conclusions, identifying four potential alternatives represented as $U = \{u_1,\ u_2,\ u_3, u_4\}$. To assess the restaurant site, they identified five parameters, indicated as $E = \{e_1, e_2, e_3, e_4, e_5\}$. The parameters e_i $(i = 1, 2, 3, 4, 5, 6)$ encompass factors such as the number of competing restaurants in the vicinity, the percentage of the local population that depends on restaurants for their meals, necessary structural modifications to the site, anticipated weekly or monthly patronage, and the accessibility of the restaurant, including sufficient parking. These factors are weighted with importance levels of 0.1, 0.3, 0.4, 0.5, and 0.7, respectively, forming the subset of parameters $Y = 0.1/e_1, 0.3/e_2, 0.4/e_3, 0.5/e_4, 0.7/e_5,$. Additionally, a set $T = \{t_1, t_2, t_3\}$ is established. Based on these findings, the committee is positioned to identify the most appropriate location for the new restaurant, leading to the development of a Fuzzy parameterized fuzzy soft expert set following extensive deliberation.*

$$
\begin{aligned}
(F,E)_t^N = \Bigg\{ & \left(\tfrac{e_1}{0.1}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.5; 0.2; 0.4\rangle}, \frac{{u_2}^{t_1}}{\langle 0.3; 0.1; 0.5\rangle}, \frac{{u_3}^{t_1}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{{u_4}^{t_1}}{\langle 0.4; 0.2; 0.3\rangle} \right\}\right), \\
& \left(\tfrac{e_2}{0.3}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.7; 0.1; 0.2\rangle}, \frac{{u_2}^{t_1}}{\langle 0.6; 0.4; 0.2\rangle}, \frac{{u_3}^{t_1}}{\langle 0.2; 0.2; 0.6\rangle}, \frac{{u_4}^{t_1}}{\langle 0.4; 0.2; 0.3\rangle} \right\}\right), \\
& \left(\tfrac{e_3}{0.4}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.8; 0.2; 0.1\rangle}, \frac{{u_2}^{t_1}}{\langle 0.6; 0.4; 0.1\rangle}, \frac{{u_3}^{t_1}}{\langle 0.3; 0.3; 0.5\rangle}, \frac{{u_4}^{t_1}}{\langle 0.4; 0.2; 0.3\rangle} \right\}\right), \\
& \left(\tfrac{e_4}{0.5}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.4; 0.4; 0.4\rangle}, \frac{{u_2}^{t_1}}{\langle 0.1; 0.3; 0.4\rangle}, \frac{{u_3}^{t_1}}{\langle 0.5; 0.6; 0.4\rangle}, \frac{{u_4}^{t_1}}{\langle 0.5; 0.3; 0.4\rangle} \right\}\right), \\
& \left(\tfrac{e_5}{0.7}, \left\{ \frac{{u_1}^{t_1}}{\langle 0.9; 0.1; 0.1\rangle}, \frac{{u_2}^{t_1}}{\langle 0.4; 0.4; 0.1\rangle}, \frac{{u_3}^{t_1}}{\langle 0.6; 0.3; 0.2\rangle}, \frac{{u_4}^{t_1}}{\langle 0.3; 0.2; 0.7\rangle} \right\}\right), \\
& \left(\tfrac{e_1}{0.1}, \left\{ \frac{{u_1}^{t_2}}{\langle 0.7; 0.2; 0.3\rangle}, \frac{{u_2}^{t_2}}{\langle 0.5; 0.1; 0.2\rangle}, \frac{{u_3}^{t_2}}{\langle 0.5; 0.3; 0.4\rangle}, \frac{{u_4}^{t_2}}{\langle 0.5; 0.3; 0.4\rangle} \right\}\right),
\end{aligned}
$$

$$\left(\frac{e_2}{0.3}, \left\{\frac{u_1{}^{t_2}}{\langle 0.6; 0.1; 0.4\rangle}, \frac{u_2{}^{t_2}}{\langle 0.5; 0.3; 0.5\rangle}, \frac{u_3{}^{t_2}}{\langle 0.3; 0.3; 0.4\rangle}, \frac{u_4{}^{t_2}}{\langle 0.7; 0.3; 0.1\rangle}\right\}\right),$$

$$\left(\frac{e_3}{0.4}, \left\{\frac{u_1{}^{t_2}}{\langle 0.5; 0.3; 0.6\rangle}, \frac{u_2{}^{t_2}}{\langle 0.3; 0.4; 0.6\rangle}, \frac{u_3{}^{t_2}}{\langle 0.1; 0.3; 0.5\rangle}, \frac{u_4{}^{t_2}}{\langle 0.4; 0.2; 0.3\rangle}\right\}\right),$$

$$\left(\frac{e_4}{0.5}, \left\{\frac{u_1{}^{t_2}}{\langle 0.4; 0.2; 0.7\rangle}, \frac{u_2{}^{t_2}}{\langle 0.5; 0.4; 0.3\rangle}, \frac{u_3{}^{t_2}}{\langle 0.4; 0.3; 0.3\rangle}, \frac{u_4{}^{t_2}}{\langle 0.7; 0.2; 0.1\rangle}\right\}\right),$$

$$\left(\frac{e_5}{0.7}, \left\{\frac{u_1{}^{t_2}}{\langle 0.2; 0.4; 0.6\rangle}, \frac{u_2{}^{t_2}}{\langle 0.7; 0.4; 0.2\rangle}, \frac{u_3{}^{t_2}}{\langle 0.4; 0.3; 0.5\rangle}, \frac{u_4{}^{t_2}}{\langle 0.3; 0.3; 0.5\rangle}\right\}\right),$$

$$\left(\frac{e_1}{0.1}, \left\{\frac{u_1{}^{t_3}}{\langle 0.7; 0.1; 0.1\rangle}, \frac{u_2{}^{t_3}}{\langle 0.8; 0.2; 0.1\rangle}, \frac{u_3{}^{t_3}}{\langle 0.7; 0.1; 0.3\rangle}, \frac{u_4{}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}\right\}\right),$$

$$\left(\frac{e_2}{0.3}, \left\{\frac{u_1{}^{t_3}}{\langle 0.1; 0.5; 0.5\rangle}, \frac{u_2{}^{t_3}}{\langle 0.5; 0.3; 0.2\rangle}, \frac{u_3{}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}, \frac{u_4{}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}\right\}\right),$$

$$\left(\frac{e_3}{0.4}, \left\{\frac{u_1{}^{t_3}}{\langle 0.9; 0.4; 0.1\rangle}, \frac{u_2{}^{t_3}}{\langle 0.7; 0.3; 0.1\rangle}, \frac{u_3{}^{t_3}}{\langle 0.5; 0.5; 0.1\rangle}, \frac{u_4{}^{t_3}}{\langle 0.4; 0.2; 0.3\rangle}\right\}\right),$$

$$\left(\frac{e_4}{0.5}, \left\{\frac{u_1{}^{t_3}}{\langle 0.3; 0.5; 0.4\rangle}, \frac{u_2{}^{t_3}}{\langle 0.6; 0.3; 0.1\rangle}, \frac{u_3{}^{t_3}}{\langle 0.5; 0.2; 0.2\rangle}, \frac{u_4{}^{t_3}}{\langle 0.5; 0.3; 0.3\rangle}\right\}\right),$$

$$\left(\frac{e_5}{0.7}, \left\{\frac{u_1{}^{t_3}}{\langle 0.1; 0.6; 0.6\rangle}, \frac{u_2{}^{t_3}}{\langle 0.6; 0.2; 0.3\rangle}, \frac{u_3{}^{t_3}}{\langle 0.5; 0.3; 0.4\rangle}, \frac{u_4{}^{t_3}}{\langle 0.5; 0.3; 0.4\rangle}\right\}\right)\Big\}.$$

5.2. Algorithm

We employ Maji's approach to determine the best course of action after converting the parameterized time neutrosophic soft set to a neutrosophic soft set. The following approach may be used to determine the choice by converting the P-TNSS to NSS. Here's how we can achieve our objective:

(i) Provide the tabular depiction of $(F, E)_t^N$.

(ii) Determine the tabular depiction. $F\,(E)$, where $F\,(E)$ is described as follows:

$$F\,(e) = \left\{\frac{u}{\langle T(e), I(e), F(e)\rangle} : u \in U, e \in E\right\} \tag{1}$$

such that

$$T(e) = \frac{\sum\limits_{i=1}^{n} \alpha_{t_i} T_{t_i}(e)}{n \max\limits_{i=1}^{n} \alpha_i(e)},$$

$$I(e) = \frac{\sum_{i=1}^{n} \alpha_{t_i} I_{t_i}(e)}{n \max_{i=1}^{n} \alpha_i(e)},$$

$$F(e) = \frac{\sum_{i=1}^{n} \alpha_{t_i} F_{t_i}(e)}{n \max_{i=1}^{n} \alpha_i(e)},$$

where $n = |T|$ and α_{t_i} the weight of t_i.

Get $F(E)$ using Maji's technique.

- Enter the Neutrosophic Soft Set $F(E)$.

- Enter P, the choice parameters of Ministry of Agriculture which is a subset of A
- Consider the NSS (H, P) and write it in tabular form.
- Calculate the comparison matrix of the NSS (H, P).
- Calculate the score S_i of u_i; $\forall i$.
- Find $S_k = \max_i S_i$.
- Any one of u_i might be the better option if k has several values.

The following outcomes are then displayed in Table 1.

Table 1: Representation of $(F, E)_t^N$

U	u_1	u_2	u_3	u_4
$\left(\frac{e_1}{0.1}, t_1\right)$	$\langle 0.5; 0.2; 0.4\rangle$	$\langle 0.3; 0.1; 0.5\rangle$	$\langle 0.4; 0.2; 0.3\rangle$	$\langle 0.4; 0.2; 0.3\rangle$
$\left(\frac{e_2}{0.3}, t_1\right)$	$\langle 0.7; 0.1; 0.2\rangle$	$\langle 0.6; 0.4; 0.2\rangle$	$\langle 0.2; 0.2; 0.6\rangle$	$\langle 0.4; 0.2; 0.3\rangle$
$\left(\frac{e_3}{0.4}, t_1\right)$	$\langle 0.8; 0.2; 0.1\rangle$	$\langle 0.6; 0.4; 0.1\rangle$	$\langle 0.3; 0.3; 0.5\rangle$	$\langle 0.4; 0.2; 0.3\rangle$
$\left(\frac{e_4}{0.5}, t_1\right)$	$\langle 0.4; 0.4; 0.4\rangle$	$\langle 0.1; 0.3; 0.4\rangle$	$\langle 0.5; 0.6; 0.4\rangle$	$\langle 0.5; 0.3; 0.4\rangle$
$\left(\frac{e_5}{0.7}, t_1\right)$	$\langle 0.9; 0.1; 0.1\rangle$	$\langle 0.4; 0.4; 0.1\rangle$	$\langle 0.6; 0.3; 0.2\rangle$	$\langle 0.3; 0.2; 0.7\rangle$
$\left(\frac{e_1}{0.1}, t_2\right)$	$\langle 0.7; 0.2; 0.3\rangle$	$\langle 0.5; 0.1; 0.2\rangle$	$\langle 0.5; 0.3; 0.4\rangle$	$\langle 0.5; 0.3; 0.4\rangle$
$\left(\frac{e_2}{0.3}, t_2\right)$	$\langle 0.6; 0.1; 0.4\rangle$	$\langle 0.5; 0.3; 0.5\rangle$	$\langle 0.3; 0.3; 0.4\rangle$	$\langle 0.7; 0.3; 0.1\rangle$
$\left(\frac{e_3}{0.4}, t_2\right)$	$\langle 0.5; 0.3; 0.6\rangle$	$\langle 0.3; 0.4; 0.6\rangle$	$\langle 0.1; 0.3; 0.5\rangle$	$\langle 0.4; 0.2; 0.3\rangle$
$\left(\frac{e_4}{0.5}, t_2\right)$	$\langle 0.4; 0.2; 0.7\rangle$	$\langle 0.5; 0.4; 0.3\rangle$	$\langle 0.4; 0.3; 0.3\rangle$	$\langle 0.7; 0.2; 0.1\rangle$
$\left(\frac{e_5}{0.7}, t_2\right)$	$\langle 0.2; 0.4; 0.6\rangle$	$\langle 0.7; 0.4; 0.2\rangle$	$\langle 0.4; 0.3; 0.5\rangle$	$\langle 0.3; 0.3; 0.5\rangle$
$\left(\frac{e_1}{0.1}, t_3\right)$	$\langle 0.7; 0.1; 0.1\rangle$	$\langle 0.8; 0.2; 0.1\rangle$	$\langle 0.7; 0.1; 0.3\rangle$	$\langle 0.4; 0.2; 0.3\rangle$
$\left(\frac{e_2}{0.3}, t_3\right)$	$\langle 0.1; 0.5; 0.5\rangle$	$\langle 0.5; 0.3; 0.2\rangle$	$\langle 0.4; 0.2; 0.3\rangle$	$\langle 0.4; 0.2; 0.3\rangle$
$\left(\frac{e_3}{0.4}, t_3\right)$	$\langle 0.9; 0.4; 0.1\rangle$	$\langle 0.7; 0.3; 0.1\rangle$	$\langle 0.5; 0.5; 0.1\rangle$	$\langle 0.4; 0.2; 0.3\rangle$

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Table 1 – continued

U	u_1	u_2	u_3	u_4
$\left(\frac{e_4}{0.5}, t_3\right)$	$\langle 0.3; 0.5; 0.4\rangle$	$\langle 0.6; 0.3; 0.1\rangle$	$\langle 0.5; 0.2; 0.2\rangle$	$\langle 0.5; 0.3; 0.3\rangle$
$\left(\frac{e_5}{0.7}, t_3\right)$	$\langle 0.1; 0.6; 0.6\rangle$	$\langle 0.6; 0.2; 0.3\rangle$	$\langle 0.5; 0.3; 0.4\rangle$	$\langle 0.5; 0.3; 0.4\rangle$

Then, using relation 1, let's say that $\alpha_{t_1} = 0.3$, $\alpha_{t_2} = 0.5$ and $\alpha_{t_3} = 0.8$,The $F(E)$ is calculated for converting the P-TNSS to NSS , We compute $F(e_1)$ for u_1 as shown below to demonstrate this step..

$$F_{u_1}(e_1) = \left\{ \frac{u_1}{\langle T(e_1), I(e_1), F(e_1)\rangle} \right\} \tag{2}$$

Where

$$\begin{aligned} T(e_1) &= \frac{0.3 * 0.5 + 0.5 * 0.7 + 0.8 * 0.7}{3 * \max\{0.3, 0.5, 0.8\}} \\ &= 1.06 / 2.4 \\ &= 0.44. \\ I(e_1) &= \frac{0.3 * 0.2 + 0.5 * 0.2 + 0.8 * 0.1}{3 * \max\{0.3, 0.5, 0.8\}} \\ &= 0.24 / 2.4 \\ &= 0.1. \\ F(e_1) &= \frac{0.3 * 0.4 + 0.5 * 0.3 + 0.8 * 0.1}{3 * \max\{0.6, 0.7, 0.9\}} \\ &= 0.35 / 2.4 \\ &= 0.14. \end{aligned}$$

Then

$$F_{u_1}(e_1) = \left\{ \frac{u_1}{\langle 0.44, 0.1, 0.14\rangle} \right\}$$

A similar method may be used to convert u_i with all parameters. Table 2 displays the conversion results.

Table 2: Representation of $F(E)$

U	u_1	u_2	u_3	u_4
e_1	$\langle 0.44, 0.1, 0.14\rangle$	$\langle 0.41, 0.1, 0.14\rangle$	$\langle 0.39, 0.12, 0.22\rangle$	$\langle 0.29, 0.15, 0.22\rangle$
e_2	$\langle 0.24, 0.2, 0.28\rangle$	$\langle 0.35, 0.21, 0.2\rangle$	$\langle 0.22, 0.15, 0.26\rangle$	$\langle 0.33, 0.15, 0.16\rangle$

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Table 2 – continued

U	u_1	u_2	u_3	u_4
e_3	$\langle 0.5, 0.22, 0.17\rangle$	$\langle 0.37, 0.23, 0.17\rangle$	$\langle 0.23, 0.27, 0.2\rangle$	$\langle 0.27, 0.13, 0.2\rangle$
e_4	$\langle 0.23, 0.26, 0.33\rangle$	$\langle 0.32, 0.22, 0.15\rangle$	$\langle 0.31, 0.2, 0.18\rangle$	$\langle 0.38, 0.15, 0.17\rangle$
e_5	$\langle 0.19, 0.3, 0.34\rangle$	$\langle 0.4, 0.2, 0.15\rangle$	$\langle 0.33, 0.2, 0.26\rangle$	$\langle 0.27, 0.19, 0.33\rangle$

The table below displays the comparison matrix of the aforementioned resultant-time neutrosophic soft.

Table 3: Comparison Matrix of P-TNSS

U	e_1	e_2	e_3	e_4	e_4
u_1	3	0	3	0	0
u_2	2	5	3	4	5
u_3	0	-1	0	0	3
u_4	0	3	-2	2	-1

Next, as seen below, we calculate the score for each u_i. (Table 4)

Table 4: Score table of P-TNSS

U	S_i
u_1	3
u_2	19
u_3	2
u_4	2

As can be seen from the score table above, u_2 may score up to 19. **Decision**The Ministry of Agriculture will choose u_2 as the land.

6. Conclusion

We have presented the idea of a parameterized time neutrosophic soft set and examined some of its characteristics in this study. The parameterized time neutrosophic soft set has been used to describe the complement, union, and intersection operations. This theory's application to a decision-making situation is provided.

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