Applications of Extended Plithogenic Sets in Plithogenic Sociogram

S.Sudha[1], Nivetha Martin[2], Florentin Smarandache[3]

[1] School of Mathematics, Madurai Kamaraj University, Madurai, Tamil Nadu, India
[2] Department of Mathematics, Arul Anandar College(Autonomous),Karumathur, Tamil Nadu, India
[3] University of New Mexico, 705 Gurley Ave., Gallup, NM 87301, USA
Emails: sudhasikkanan@gmail.com; nivetha.martin710@gmail.com; fsmarandache@gmail.com

Abstract

The theory of plithogeny developed by Smarandache is described as a more generalized form of representing sets of different nature such as crisp, fuzzy, intuitionistic and neutrosophic. Plithogenic set comprises degree of appurtenance and contradiction degree with respect only to the dominant attribute. This paper introduces extended plithogenic sets comprising degrees of appurtenance and contradiction with respect to both dominant and recessive attributes. The extension of the 5-tuple Plithogenic sets to a 7- tuple plithogenic sets helps in developing a more comprehensive kind of Plithogenic sociogram. The newly developed plithogenic sets and its implications in Plithogenic sociogram is validated by the decision making problem on food processing industries. The obtained results using extended plithogenic sets are more promising in comparison to the conventional plithogenic sets. The proposed kind of plithogenic sets will benefit the decision makers to make optimal decisions based on both optimistic and pessimistic approaches.

Keywords: Plithogenic Sociogram; Extended Plithogenic Sets; Food Packaging materials; Decision making

1. Introduction

Plithogenic sets introduced by Smarandache in 2018 [1] have generalized the representations of both the conventional crisp sets and contemporary sets such as fuzzy sets, intuitionistic sets and neutrosophic sets. A plithogenic set is a 5-tuple set of the form (P,a,V,d,c) comprising 5 components namely a set P, the attribute a, the attribute values V, the degree of appurtenance d and the contradiction degree c. The classification of plithogenic sets into crisp, fuzzy, intuitionistic and neutrosophic sets is based on the respective crisp, fuzzy, intuitionistic and neutrosophic values of d. Thus the degree of appurtenance serves as the deciding factor of the nature of Plithogenic sets. Smarandache[2,3] have well presented the theoretical framework of Plithogenic sets, Plithogenic logic, Plithogenic probability and also the generalized versions of the above with suitable practical implications.[1-3]

Plithogenic sets are recently applied in several decision making problems especially in multi-criteria decision making problems (MCDM) because of the significant characteristic of Plithogenic sets in handling of attribute and attribute values. Under Plithogenic MCDM, the methods are further extended with Plithogenic arguments. For instance the method of TOPSIS is discussed under Plithogeny in which the plithogenic representations and plithogenic operators are used. Sankar et al [4] have applied Plithogenic TOPSIS (PTOPSIS) to obtain optimal ranking of the alternatives of the decision making problem on COVID 19. Researchers have also integrated Plithogenic TOPSIS with other MCDM methods. To mention a few, PTOPSIS-CRITIC by Basset et al [5] in sustainability risk analysis, SWARA-PTOPSIS by Martin et al [6] in food processing industries. The other MCDM method explored

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

under plithogeny is Plithogenic MARICA by Abdullah et al [7]. From the literature the applications of Plithogenic sets in diverse fields are very evident. To mention some of the significant contributions of the researchers, Mohamed et al [8] in IOT based supply chain, Shio et al [9] with entropy measures, Basset et al [10] in supplier selection, Gomathy et al [11] in decision making, Abdel et al [12] in choosing sustainability metrics, Priyadharshini et al [13,14] in multi criteria decision making with refined plithogenic neutrosophic sets, Abdel et al [15,16] in assessing financial performance, hospital care system. In addition to MCDM applications the plithogenic sets are also associated with other decision making tools with further extensions and theoretical arguments.

Researchers have integrated the theory of plithogeny with soft and Hypersoft sets to evolve hybrid decision making techniques. Smarandache [17] has given key contributions to the theory of Plithogenic Hypersoft sets by extending soft sets to Hypersoft sets. Alkhazaleh et al [18] introduced Plithogenc softs sets. Rana et al [19] developed Plithogenic fuzzy whole hypersoft set with applications in constructing frequency matrix. Dhivya et al [20] introduced near plithogenic neutrosophic Hypersoft sets with Heronian Mean Aggregation Operators. Muhammad et al [21] have described Plithogenic Hypersoft Sets under Fuzzy Neutrosophic Environment. Shazia et al [22] introduced the notion of Plithogenic Subjective Hyper-Super-Soft Matrices. Martin et al[23-25] conceptualized combined Hypersoft sets, extended plithogenic Hypersoft sets in covid diagnosis and associated with concentric plithogenic hypergrpahs. Plithogenic graphs and hypergraphs are also initiated by the researchers. Vasantha and Smarandache [26] introduced the theory of Plithogenic graphs. Sultana[27] applied plithogenic graphs in disease diagnosis. Gayen et al [28] developed the notion of Plithogenic Hypersoft set subgroup, Martin et al [29] introduced PROMTHEE Plithogenic Pythagorean Hypergraphic Approach in decision making on smart materials, Singh [30-32] has applied Single-valued Plithogenic graph, Single-Valued Neutrosophic Plithogenic, Single-Valued Neutrosophic Plithogenic in data analysis and optimization. Bharathi and Leo [33] used Plithogenic Product Fuzzy Graphs in analysing social networks.

The concept of Plithogeny is also applied to define various algebraic structures and topological spaces. Gayen et al [28,34] introduced and analyzed the properties of plithogenic subgroup, plithogenic Hypersoft subgroup. Priyadharshini and Nirmala [35] have investigated on the theoretical ideas of Plithogenic Neutrosophic Topological Spaces. Bhimraj [36] contributed to the theory of Plithogenic Neutrosophic Hypersoft Almost Topological Group, plithogenic cubic sets and with orders P and R. Singh [37] has developed complex plithogenic set. Martin et al [38] introduced the notion of Plithogenic numbers. Noel et al [39] applied Plithogenic numbers in assessing Entrepreneurship Competence in University Students and Raúl [40] in evaluating the performances. The theory of Plithogenic Cognitive Maps, New Plithogenic Sub Cognitive Maps and Induced Plithogenic Cognitive Maps are introduced by Nivetha and Smarandache [41-43]. These novel concepts are applied in making decisions on disease diagnosis, learning systems. Sujatha et al [44] applied Plithogenic Cognitive Maps in diagnosing novel coronavirus.

The comprehensive nature of the Plithogenic sets has widened its extent of applications to various other fields especially to the domain of Physical sciences. Smarandache [45,46] coined the aspect of Physical Plithogenic sets and have applied aggregate operators in physical filed. Bala [47] applied plithogenic sets and logic in handling information. Walid [48] integrated Plithogenic sets with mathematical programming in making assessments , Ariel et al [49] in the domain of management, Gustavo [50] in the educational filed. The theory of Plithogeny is applied in the field of social science and this has motivated the researchers to develop Plithogenic sociogram (PS) an integrated sociometric technique which is an extended version of neutrosophic sociogram (NS) applied in group analysis. The main objective of neutrosophic sociogram is to make a quantitative measurement of the group dynamics. The possibilities of enhancing the degree of association between the members of the group are determined using NS by considering both positive and negative preferentialism. Based on the framework of NS, PS is constructed only using positive preferentialism by considering the degrees of appurtenances and contradiction degrees only with respect to the dominant attribute values. On observing the theoretical conceptualization and practical implications of NS and PS from the literature, the following findings are determined

(i) In NS, the decision making is dependent on both the positive and negative preferential scores representing their interest and disinterest in associating oneself with the group members. Also the final score values obtained using both the types of preferentialism helped in making interpretations on the possibilities of increasing the relationship between the members of the group

(ii) In PS, the decision making is based only on the positive preferentialism (i.e) it is based only on the dominant attribute values. The final scores based on only positive preferences helped in ranking the persons based on their preferential scores, but the possibility of enhancing the relationship is not able to be determined in Plithogenic sociogram approach of group analysis.

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

On intense analysis, in Plithogenic sociogram the preferential scores are based only on the degree of appurtenance with respect to only one dominant attribute value i.e the positive preferentialism, whereas the space for negative preferentialism is nil as the components d and c of the plithogenic set are confined only to the dominant attribute value. This shortcoming of PS has motivated the authors to extend the 5-tuple plithogenic set to 7-tuple plithogenic set by considering the degree of appurtenance and contradiction degree with respect to recessive attribute value in addition to dominant attribute value to calculate the negative preferential score. The main outcome of such extended kind of plithogenic sets will make PS better than NS in the following contexts

(i) The members of the group shall be ranked based on both positive and negative preferentialism

(ii) The possibilities of enhancing the relationship between the members shall also be determined based on both dominant and recessive attribute values.

To bridge this research gap, an extended form of plithogenic set (ExPlS) is introduced in this research work. The theoretical construction of ExPlS is presented in section 2, the conceptualization and the algorithm of Plithogenic sociogram with extended plithogenic sets is presented in section 3, the application of the proposed PS with ExPlS is presented in section 4 with respect to a decision making problem on food processing industries. Section 5 presents the comparative analysis and the results. The last section concludes the work.

2. Conceptualization of Extended Plithogenic Sets (ExPlS)

This section presents the theoretical developments of extended plithogenic sets which is the extension of the existing plithogenic sets developed by Smarandache.

Based on the previous theoretical genesis of plithogeny, the plithogenic set of the form (P,a,V,d,c) is extended to(P,a,V,d_D,c_D,d_R,c_R) where

d_D – the degree of appurtenance is with respect to dominant attribute value

c_D-the contradiction degree with respect to dominant attribute value

d_R – the degree of appurtenance is with respect to recessive attribute value

c_R - the contradiction degree with respect to recessive attribute value

The differences between the extended plithogenic sets and the conventional plithogenic sets are the inclusions of degree of appurtenance and contradiction with respect to recessive attribute value in addition to that of the dominant attribute value.

Let us consider an example to explain the representation of ExPlS.

Let P be a set be representing the products {P1,P2,P3,P4,P5}

Generally, the expected attributes considered in purchasing the products are price, quality

The attribute values of price are {cheap, budgetary, expensive} = {P11,P12,P13}

The attribute values of the quality are {low, moderate, high} ={Q11,Q12,Q13}

In this case, let us consider the attribute price with attribute values as P11,P12 and P13. Let the dominant attribute value be cheap and recessive attribute value be expensive. The ExPlS considers the degrees of appurtenances and contradiction degrees with respect to both dominant and recessive attribute value pertinent to the attribute of price.

2.1 Classification of ExPlS

The ExPlS shall be classified based on the degrees of appurtenance with respect to both dominant and recessive attribute values.

2.1.1 Crisp ExPlS

AExPls is said to be crisp if dD and dR are crisp in nature.

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

$d_D : P \times V \to \{0,1\}$ & $d_R : P \times V \to \{0,1\}$ and $c_D : V \times V \to \{0,1\}$ & $c_R : P \times V \to \{0,1\}$

2.1.2 Fuzzy ExPlS

If dD and dR are fuzzy sets, A ExPls is described to as a Fuzzy ExPlS.

$d_D : P \times V \to [0,1]$ & $d_R : P \times V \to [0,1]$and $c_D : V \times V \to [0,1]$ & $c_R : P \times V \to [0,1]$

2.1.3 Intuitionistic ExPlS

If dD and dR are Intuitionistic fuzzy sets, then ExPls is refered to as anIntuitionistic fuzzy ExPlS.

$d_D : P \times V \to [0,1]^2$& $d_R : P \times V \to [0,1]^2$and $c_D : V \times V \to [0,1]$ & $c_R : P \times V \to [0,1]$

2.1.4 Neutrosophic ExPlS

If dD and dR are Neutrosophic fuzzy values ,then an ExPls is referred to as a Neutrosophic ExPlS

$d_D : P \times V \to [0,1]^3$& $d_R : P \times V \to [0,1]^3$and $c_D : V \times V \to [0,1]$ & $c_R : P \times V \to [0,1]$

The different degrees of appurtenance with respect to both dominant and recessive attribute values of the attribute price and quality are presented in the following Table 2.1. Let us consider the dominant attribute value of price is cheap and the recessive attribute value as expensive. Let us also consider the dominant attribute value of quality as high and the recessive attribute value as low

Table 1: represents Contradiction Degree with respect to Dominant attribute value and recessive attribute value for Price

Attribute: Price									
Contradiction Degree with respect to Dominant attribute value		0	1/3	2/3	Contradiction Degree with respect to Recessive attribute value		2/3	1/3	0
Attribute values		**P11**	P12	P13	Attribute values		P11	P12	**P13**
Crisp degree of appurtenance	P1	1	0	0	Crisp degree of appurtenance	P1	0	0	1
	P2	0	1	0		P2	0	1	0
	P3	0	0	1		P3	1	0	0
	P4	1	0	0		P4	0	0	1
	P5	0	1	0		P5	0	1	0
Fuzzy degree of appurtenance	P1	0.8	0.2	0.1	Fuzzy degree of appurtenance	P1	0.3	0.4	0.7
	P2	0.1	0.9	0.2		P2	0.2	0.8	0.3
	P3	0.2	0.3	0.8		P3	0.9	0.2	0.1
	P4	0.9	0.2	0.1		P4	0.1	0.3	0.9
	P5	0.2	0.7	0.2		P5	0.3	0.8	0.1
Intuitionistic degree of	P1	(0.7, 0.2)	(0.2, 0.8)	(0.1, 0.9)	Intuitionistic degree of	P1	(0.3,0.9)	(0.4,0.8)	(0.7, 0.2)

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

appurtenance	P2	(0.1, 0.8)	(0.9, 0.1)	(0.2, 0.7)	appurtenance	P2	(0.2,0.7)	(0.8, 0.1)	(0.3, 0.6)
	P3	(0.2, 0.7)	(0.3, 0.7)	(0.8, 0.2)		P3	(0.9,0.1)	(0.2,0.7)	(0.1, 0.7)
	P4	(0.8, 0.3)	(0.2, 0.6)	0.1, 0.7)		P4	(0.1,0.6)	(0.3,0.7)	(0.9, 0.2)
	P5	(0.2, 0.7)	(0.7, 0.1)	(0.2, 0.8)		P5	(0.3,0.8)	(0.8,0.1)	(0.1, 0.9)
Neutrosophic degree of appurtenance	P1	(0.7, 0.2, 0.1)	(0.2, 0.8, 0.1)	(0.1, 0.9, 0.3)	Neutrosophic degree of appurtenance	P1	(0.3,0.9,0.2)	(0.4, 0.8,0.1)	(0.7, 0.2,0.2)
	P2	(0.1, 0.8, 0.2)	(0.9, 0.1, 0.1)	(0.2, 0.7, 0.3)		P2	(0.2,0.7,0.3)	(0.8, 0.1,0.2)	(0.3, 0.6, 0.2)
	P3	(0.2, 0.7, 0.3)	(0.3, 0.8, 0.1)	(0.9, 0.2, 0.2)		P3	(0.9,0.1,0.3)	(0.2,0.7, 0.1)	(0.1, 0.7, 0.3)
	P4	(0.8, 0.1, 0.2)	(0.2, 0.7, 0.1)	0.1, 0.7, 0.3)		P4	(0.1,0.6,o.2)	(0.3,0.7, 0.1)	(0.9, 0.2, 0.3)
	P5	(0.1, 0.7, 0.3)	(0.7, 0.1, 0.2)	(0.2, 0.8, 0.2)		P5	(0.3,0.8,0.2)	(0.8,0.1, 0.3)	(0.1, 0.9, 0.2)

According to the dominant attribute value and recessive attribute value for Quality,

Table 2: shows different forms of contradiction degrees.

Attribute: Quality									
Contradiction Degree with respect to Dominant attribute value		0	1/3	2/3	Contradiction Degree with respect to Recessive attribute value		2/3	1/3	0
Attribute values		**Q11**	Q12	Q13	Attribute values		Q11	Q12	**Q13**
Crisp degree of appurtenance	P1	1	0	0	Crisp degree of appurtenance	P1	0	0	1
	P2	0	1	0		P2	0	1	0
	P3	0	0	1		P3	1	0	0
	P4	1	0	0		P4	0	0	1
	P5	0	1	0		P5	0	1	0
Fuzzy degree of appurtenance	P1	0.85	0.2	0.15	Fuzzy degree of appurtenance	P1	0.3	0.3	0.75
	P2	0.1	0.75	0.2		P2	0.2	0.85	0.1

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

	P3	0.2	0.2	0.8		P3	0.9	0.1	0.1
	P4	0.95	0.2	0.2		P4	0.1	0.2	0.8
	P5	0.1	0.7	0.1		P5	0.3	0.8	0.1
Intuitionistic degree of appurtenance	P1	(0.7,0.2)	(0.2,0.9)	(0.1,0.85)	Intuitionistic degree of appurtenance	P1	(0.3,0.7)	(0.3, 0.8)	(0.7, 0.1)
	P2	(0.1,0.7)	(0.8,0.1)	(0.2,0.8)		P2	(0.2,0.6)	(0.8, 0.2)	(0.3, 0.75)
	P3	(0.2,0.9)	(0.3,0.8)	(0.8,0.15)		P3	(0.9,0.3)	(0.2,0.8)	(0.2, 0.7)
	P4	(0.95, 0.3)	(0.2,0.65)	0.2, 0.7)		P4	(0.1,0.8)	(0.2,0.75)	(0.8, 0.1)
	P5	(0.1,0.7)	(0.7,0.1)	(0.1,0.9)		P5	(0.3,0.9)	(0.8,0.1)	(0.1, 0.7)
Neutrosophic degree of appurtenance	P1	(0.7,0.2, 0.2)	(0.2,0.9, 0.1)	(0.1,0.9, 0.1)	Neutrosophic degree of appurtenance	P1	(0.3,0.8,0.1)	(0.2, 0.9,0.1)	(0.75, 0.2,0.1)
	P2	(0.2,0.85, 0.2)	(0.8,0.1, 0.1)	(0.2,0.75, 0.2)		P2	(0.1,0.7,0.1)	(0.8, 0.1,0.1)	(0.3, 0.7, 0.1)
	P3	(0.2,0.8, 0.1)	(0.2,0.8, 0.2)	(0.8,0.2, 0.1)		P3	(0.9,0.1,0.1)	(0.1,0.75, 0.1)	(0.1, 0.75, 0.1)
	P4	(0.9,0.2, 0.2)	(0.2,0.7, 0.2)	(0.1, 0.8, 0.2)		P4	(0.1,0.7,o.1)	(0.2,0.7, 0.2)	(0.8, 0.2, 0.1)
	P5	(0.1,0.7, 0.15)	(0.7,0.15, 0.2)	(0.1,0.8, 0.1)		P5	(0.1,0.8,0.1)	(0.8,0.1, 0.2)	(0.1, 0.8, 0.2)

Thus in an extended plithogenic set, both the dominant and recessive attribute values are considered for each of the attribute to make comprehensive decisions. Also in the table 2.1 & 2.2, the nature of both the dominant and recessive attribute values are of same type (either crisp, fuzzy, intuitionistic or neutrosophic) but in realistic perspective, the values of dD and dR may occur in combination with different representations giving a new look of mixed type of ExPlS. It is illustrated in Table 2.3.

Table 3: Illustration of Mixed Extended Plithogenic Sets

Attribute: Price									
Contradiction Degree with respect to Dominant attribute value		0	1/3	2/3	Contradiction Degree with respect to Recessive attribute value		2/3	1/3	0
Attribute values		**P11**	P12	P13	Attribute values		P11	P12	**P13**
Crisp degree of appurtenance	P1	1	0	0	Fuzzy degree of appurtenance	P1	0.1	0.1	0.75

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

	P2	0	1	0		P2	0.25	0.8	0.15
	P3	0	0	1		P3	0.9	0.15	0.1
	P4	1	0	0		P4	0.1	0.1	0.85
	P5	0	1	0		P5	0.2	0.8	0.2
Fuzzy degree of appurtenance	P1	0.8	0.2	0.2	Intuitionistic degree of appurtenance	P1	(0.1,0.7)	(0.2, 0.7)	(0.7, 0.2)
	P2	0.15	0.65	0.2		P2	(0.2,0.65)	(0.8, 0.3)	(0.2, 0.7)
	P3	0.2	0.25	0.7		P3	(0.9,0.2)	(0.2,0.7)	(0.2, 0.7)
	P4	0.9	0.1	0.1		P4	(0.1,0.9)	(0.2,0.85)	(0.8, 0.2)
	P5	0.1	0.9	0.15		P5	(0.2,0.8)	(0.8 ,0.1)	(0.1, 0.75)
Intuitionistic degree of appurtenance	P1	(0.8,0.2)	(0.2,0.9)	(0.2, 0.8)	Neutrosophic degree of appurtenance	P1	(0.1,0.7,0.1)	(0.2, 0.75,0.1)	(0.75, 0.1,0.1)
	P2	(0.15, 0.7)	(0.65, 0.1)	(0.2, 0.8)		P2	(0.1,0.7,0.1)	(0.8, 0.3,0.1)	(0.2, 0.7, 0.1)
	P3	(0.2,0.9)	(0.3,0.8)	(0.7, 0.1)		P3	(0.9,0.1,0.1)	(0.1,0.7, 0.1)	(0.1, 0.75, 0.1)
	P4	(0.9,0.1)	(0.2,0.7)	(0.2, 0.7)		P4	(0.1,0.8,o.1)	(0.2,0.85, 0.2)	(0.8, 0.2, 0.1)
	P5	(0.1,0.75)	(0.8,0.1)	(0.1, 0.8)		P5	(0.2,0.7,0.1)	(0.8,0.1, 0.2)	(0.1, 0.8, 0.2)
Neutrosophic degree of appurtenance	P1	(0.8,0.2, 0.2)	(0.2,0.9, 0.1)	(0.1, 0.9, 0.2)	Crisp degree of appurtenance	P1	0	0	1
	P2	(0.2,0.8, 0.2)	(0.8,0.1, 0.1)	(0.1, 0.7, 0.2)		P2	0	1	0
	P3	(0.2,0.8, 0.1)	(0.2,0.8, 0.1)	(0.6, 0.2, 0.1)		P3	1	0	0
	P4	(0.9,0.1, 0.2)	(0.2,0.7, 0.2)	(0.1, 0.8, 0.2)		P4	0	0	1
	P5	(0.1,0.7, 0.1)	(0.8,0.1, 0.2)	(0.1, 0.8, 0.1)		P5	0	1	0

One may question on the need of such a kind of extended plithogenic sets. Generally the dominant attribute values of the attributes are considered which is referred to the most desirable attribute value by the decision makers. In multi-criteria decision making scenario, this kind of approach will facilitate to make decisions on the best of the best alternatives. But at the same time, at certain instances the decision makers need to find the worst of the worst and best of the worst alternatives to avoid them from entering the choice list of decision making. The determination of the worst alternatives shall be found easily by considering recessive attribute values. Henceforth the extended plithogenic sets are developed in this

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

section with the above substantiating arguments. The applications of extended plithogenic sets are presented in the following sections.

3. Extended Plithogenic Sociogram

Plithogenic Sociogram introduced by Nivetha and Smarandache [38] is an extension of neutrosophic sociogram. To investigate the magnitude of the association between the members of the group, the affirmative and indeterminate nature of establishing relationship between the members are considered. Following the same fashion, in Plithogenic sociogram the affirmative kind of relationship is considered only with respect to dominant attribute value of each of the attribute. To obtain the non-affirmative nature of relationship between the members, the recessive attribute values must be identified and included in the representation for which the extended plithogenic sets highly facilitate. The algorithm of Extended Plithogenic Sociogram and the applications with respect to group dynamics are presented in this section with an example.

3.1 Algorithm of Extended Plithogenic Sociogram

This sub section elucidates the steps involved in computing the ranking preferences using Plithogenic sociogram with ExPls. The above step wise procedure is consolidated and presented in the form of an algorithm for better understanding of the readers.

Step 1: The decision making problem is well defined and the set of preferences (alternatives) say {M1,M2,M3,..Mn}, set of attributes say {Q1,Q2,Q3,…Qm} and set of attribute values say {Q11, Q12,Q13,..Q1p} for the attribute Q11, {Q21,Q22,Q23,..Q2p} for the attribute Q2 and so on are decided based on the expert's opinion along with degree of appurtenance (either crisp, fuzzy, intuitionistic or neutrosophic) and the contradiction degree.

Step 2: The decisions on choosing both the dominant and recessive attribute values with respect to each of the attributes are made.

Step 3: The table comprising the Plithogenic representations of preferential and non-preferential choice making of the alternatives with respect to the dominant and recessive attribute values is constructed as follows

Alternatives	**Preferential choice making based on the dominant attribute values**	**Non-preferential choice making based on the recessive attribute values**
M_1	{M2(Q12(M_1x_{12}),Q21(M1x_{21})….,Qmp(M1x_{mp})), M3(Q12(M1y_{12}),Q21(M1y_{21})…,Qmp(M1y_{mp})),…. Mn(Q12(M1v12),Q21(M1v21),Qmp(M1vmp))}	{M4(Q11(M1z11),Q23(M1z23),….,Qm-1p-1 (M1$z_{(m-,1)(p-1)}$), …… Mn-1(Q11(M1w11),Q23(M1w23),….,Q m-1p-1 (M1$w_{(m-,1)(p-1)}$))}
. . . . .	… … … … … … … … … … … … …. …. …. …. …. ….	… … … … … … … … … … …. …. …. …. ….
M_n	M1(Q12(Mnf12),Q21(Mnf21),….,Qmp(Mnfmp)), M4(Q12(Mnz12),Q21(Mnz21),….,Qmp(Mnzmp))}… Mn-3(Q12(Mne12),Q21(Mne21),Qmp(Mnemp))}	{ M1(Q11(Mnf11),Q23(Mnf23),..,Qm-2p-1(Mnf$_{(m-2)(p-1)}$)), M2(Q11(Mnx11),Q23(Mnx23),…, Qm-2p-1(Mnx$_{(m-2)(p-1)}$)),……, Mn-2(Q11(Mng11),Q23(Mng23),),…, Qm-2p-1(Mng$_{(m-2)(p-1)}$))}

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

The expression in the first row representing the preferential choice making is $M1 \rightarrow \{M2(Q12(M_1x_{12}),Q21(M1x_{21})\ldots,Qmp(M1x_{mp})),M3(Q12(M1y_{12}),Q21(M1y_{21})\ldots,Qmp(M1y_{mp})),\ldots,$ $Mn(Q12(M1v12),Q21(M1v21),Qmp(M1vmp))\}$ shall be understood as follows,

The alternative M1 prefers M2 with respect to the dominant attribute values Q12,Q21,.. , Qmp and the respective preferential values are M1x12, $M1x_{21\ldots,}$ $M1x_{mp.}$

Similarly, the expression representing the non-preferential choice making is $M1 \rightarrow \{M4(Q11(M1x11),Q23(M1x23),\ldots,Qm\text{-}1p\text{-}1\ (M1x_{(m-,1)(p-1)}), \ldots$

$Mn\text{-}1(Q11(M1w11),Q23(M1w23),\ldots,Q\ m\text{-}1p\text{-}1\ (M1w_{(m-,1)(p-1)}))\}$ shall be understood as follows,

The alternative M1 do not prefers M4 with respect to the recessive attribute values Q11,Q23,.. , Q(m-1)(p-1) and the respective non-preferential values are M1x11, $M1x_{23\ldots,}$ M1x(m-1)(p-1). The same kind of interpretations shall be made from the above representations for other alternative preferences.

.

Step 4: The Evaluation matrix of the below form is constructed for each of the dominant attribute values and recessive attribute values. Let us consider for instance the attribute values Q12 and Q11 are dominant and recessive respectively.

	M_1	M_2	M_3	M_4	…..	Mn-3	……..	M_n
M_1	0	M_1x_{12}	M_1y_{12}	0	……	0	…..	M_1v_{12}
.	…	…	…	…	…	…	…	…
.	…	…	…	…	…	…	…	…
. .	….	….	….	….	….	….	….	….
Mn	M_nf_{12}	0	0	M_nz_{12}	…..	M_ne_{12}	……	0

	M_1	M_2	M_3	M_4	…..	M_{n-2}	M_{n-1}	M_n
M_1	0	0	0	M_1z11	……	0	M1w11	0
.	…	…	…	…	…	…	…	…
.	…	…	…	…	…	…	…	…
. .	….	….	….	….	….	….	….	….
Mn	Mnf11	Mnx11	0	0	……	Mng11	0	0

Step 5: The combined evaluation matrix with respect to the dominant attribute values is determined first by multiplying the weights w_k of the dominant attribute values with the corresponding evaluation matrix obtained with respect to each of the dominant attribute values and then the evaluation matrices are summed up together. The combined evaluation matrix with respect to the recessive attribute values is obtained similarly.

Step 6: The plithogenic amicability degree pD_{ij} with respect to dominant attribute values is obtained using $\frac{2}{pD_{ij}} = \frac{1}{u_{ij}} + \frac{1}{u_{ji}}$, where u_{ij} stands for the degree of compatibility between members i and j, indicating that member i favours member j and vice versa. The plithogenic amicability degree pR_{ij} is also calculated with respect to recessive attribute values.

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

Step 7: The score values for the alternatives are obtained from the plithogenic amicability degree values with respect to both the dominant and recessive attribute values using $F_D(S_g) = \frac{\sum_j pD_{ij}}{\sum_i \sum_j pD_{ij}}$ and $F_R(S_g) = \frac{\sum_j pR_{ij}}{\sum_i \sum_j pR_{ij}}$ respectively

Step 8: The alternatives are ranked separately both with respect to dominant and recessive attribute values. In the context of dominant attribute values, the alternatives with highest scores are given first priorities and in the context of recessive attribute values, the alternatives with least scores are given first priorities.

Step 9: The overall ranking of the alternatives using both the dominant and recessive attribute values is determined by finding the deviations between $F_D(S_g)$ and $F_R(S_g)$. The alternatives with smallest magnitude of deviations are given priorities.

3.2 Example of Plithogenic Sociogram

The example presented in this section is based on [38] is considered with few modifications. Let us consider a situation where the students are asked to group themselves and they are also asked to give their preferential choices of grouping.

Let M = {M1, M2, M3, M4, M5} be the students who are subjected to the following questions. Their preferential choices are collected based on not just with the questions but also with the attribute values.

Write your friends with whom you wish to group with respect to the

Q1: Type of personality

Q2: Social skills

Q3: Degree of Compassion

Here in this case the attributes are the Type of personality, social skills and degree of compassion. The attribute values of the attributes are as follows

Type of Personality = {introvert (Q11), extrovert (Q12), ambivert (Q13)}.

Social skills = {Excellent (Q21), good (Q22), average (Q23)}.

Degree of compassion = {low (Q31), moderate (Q32), high (Q33)}.

In the above example, the dominant attribute values are Q12, Q21, Q33 and the recessive attribute values are Q11, Q23, Q31.

In the case of affirmative preferential choice making, the dominant attribute values Q12, Q21,Q33 are considered, whereas in the case of non-affirmative or non-preferential choice making, the recessive attribute values Q11, Q23, Q31 are considered. Based on these assumptions, the following table 3.1 presents both the affirmative and non-affirmative fuzzy preferential choice making based on respective dominant and recessive attribute values among the five students is presented.

Table 4: Preferential choice making based on the dominant attribute values and Non-preferential choice making based on the recessive attribute values

Students	**Preferential choice making based on the dominant attribute values**	**Non-preferential choice making based on the recessive attribute values**
M_1	{ M2(Q12(0.5),Q21(0.6),Q33(0.8)), M3(Q12(0.5),Q21(0.65),Q33(0.7)), M5(Q12(0.4),Q21(0.3),Q33(0.45))}	{M4(Q11(0.6),Q23(0.7),Q31(0.8)), M2(Q11(0.7),Q23(0.6),Q31(0.65))}
M_2	{M1(Q12(0.8),Q21(0.8),Q33(0.8)), M3(Q12(0.6),Q21(0.5),Q33(0.56)),	{M1(Q11(0.6),Q23(0.7),Q31(0.8)),

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

	M5(Q12(0.6),Q21(0.7),Q33(0.8))}	M3(Q11(0.75),Q23(0.6),Q31(0.6)), M5(Q11(0.7),Q23(0.6),Q31(0.65))}
M_3	M1(Q12(0.8),Q21(0.7),Q33(0.75)), M4(Q12(0.65),Q21(0.5),Q33(0.65))}	{ M1(Q11(0.75),Q23(0.5),Q31(0.65)), M2(Q11(0.65),Q23(0.7),Q31(0.9)), M5(Q11(0.45),Q23(0.65),Q31(0.75))}
M_4	M1(Q12(0.55),Q21(0.75),Q33(0.8)), M5(Q12(0.6),Q21(0.45),Q33(0.7))}	M1(Q11(0.8),Q23(0.7),Q31(0.7)), M3(Q11(0.7),Q23(0.5),Q31(0.85)), M5(Q11(0.5),Q23(0.6),Q31(0.8))}
M_5	M1(Q12(0.5),Q21(0.75,Q33(0.8)), M3(Q12(0.75),Q21(0.7),Q33(0.55)), M4(Q12(0.7),Q21(0.6),Q33(0.7))}	M2(Q11(0.85),Q23(0.65),Q31(0.75)), M4(Q11(0.7),Q23(0.5),Q31(0.85))}

In the above table the preferential choice making of the student m1 is based on dominant attribute values of extrovert type of personality, excellent social skills and high degree of compassion. According to the student M1, the preferential score values given to the student M3 based on the respective dominant attribute values are 0.5, 0.6, and 0.8. Similarly the student M1 has given the non-preferential score value in grouping with the student M4 based on the recessive attribute values of introvert type of personality, average social skills and low degree of compassion. The respective score values are 0.6, 0.7 and 0.8.

The evaluation matrix for each of the attribute values is framed based on the approach of Plithogenic sociogram as described by Nivetha and Smarandache [52] and for better understanding the authors shall refer the same. The above problem is discussed under two cases.

Case (1a)

3.2.1 Ranking the alternatives based on equal weightage of dominant attribute values

Table 3.2,3.3, 3.4 present the evaluation matrix for the dominant attribute value Q12,Q21andQ 33.

Table 5: Evaluation matrix M_{D1} for the dominant attribute value Q12

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.5	0.5	0	0.4
M_2	0.8	0	0.6	0	0.6
M_3	0.8	0	0	0.65	0
M_4	0.55	0	0	0	0.6
M_5	0.5	0.75	0	0.7	0

Table 6: Evaluation matrix M_{D2} for the dominant attribute value Q21

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.6	0.65	0	0.3
M_2	0.8	0	0.5	0	0.7
M_3	0.7	0	0	0.5	0
M_4	0.75	0	0	0	0.45

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

M_5	0.75	0.7	0	0.6	0

Table 7: Evaluation matrix M_{D3} for the dominant attribute value Q33

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.8	0.7	0	0.45
M_2	0.8	0	0.56	0	0.8
M_3	0.75	0	0	0.65	0
M_4	0.8	0	0	0	0.7
M_5	0.8	0.55	0	0.7	0

The combined matrix comprising the aggregate dominant attribute values with equal weightage (0.33 each) is present in Table 8

Table 8: Combined Matrix with equal weightage to Dominant Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.627	0.611	0	0.3795
M_2	0.792	0	0.548	0	0.693
M_3	0.7425	0	0	0.594	0
M_4	0.693	0	0	0	0.5775
M_5	0.677	0.66	0	0.66	0

The plithogenic amicability degree p_{ij} is obtained using Eq.3.1

$$\frac{2}{pD_{ij}} = \frac{1}{u_{ij}} + \frac{1}{u_{ji}} \qquad \text{------------------ (3.1)}$$

where u_{ij} stands for the degree of compatibility between members i and j, indicating that member i favours member j and vice versa.

Table 9: Measure of Amicability Degree with equal weightage to Dominant Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.699	0.6704	0	0.4864
M_2	0.699	0	0	0	0.6761
M_3	0.6704	0	0	0	0
M_4	0	0	0	0	0.616
M_5	0.4864	0.6761	0	0.616	0

The score values for the alternatives are obtained using Eq.3.2 and it is represented in Table 3.7

$$F_D(Sg) = \frac{\sum_j pD_{ij}}{\sum_i \sum_j pD_{ij}} \qquad \text{--------------------------(3.2)}$$

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

Table 10: Final Ranking of the Alternatives with equal weightage to Dominant Attribute Values

Alternatives	**Score Value**	**Ranking of Alternatives**
M_1	0.2948	1
M_2	0.2184	3
M_3	0.1065	4
M_4	0.0978	5
M_5	0.2825	2

The alternatives are ranked based on their score values. The alternatives with maximum score values are highly preferred.

Case (1b)

3.2.2 Ranking the alternatives based on unequal weightage of dominant attribute values

The combined matrix shall be obtained by considering unequal weights to the dominant attribute values. In this case, the weights are assigned as follows W (Q12) =0.5, W(Q21) =0.25, W(Q33)=0.25 and Table 3.8 represents the aggregate values .

Table 11: Combined Matrix with unequal weightage to Dominant Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.6	0.5875	0	0.3875
M_2	0.8	0	0.565	0	0.675
M_3	0.763	0	0	0.6125	0
M_4	0.6625	0	0	0	0.5875
M_5	0.6375	0.6875	0	0.675	0

The plithogenic amicability degree obtained using Eq.3.1 is presented in Table 3.9

Table 12: Measure of Amicability Degree with unequal weightage to Dominant Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.6857	0.6638	0	0.482
M_2	0.6857	0	0	0	0.6812
M_3	0.6638	0	0	0	0
M_4	0	0	0	0	0.6282
M_5	0.482	0.6812	0	0.6282	0

The score values for the alternatives obtained using Eq. 3.2 are shown in the Table 3.10

Table 13: Final Ranking of the Alternatives with unequal weightage to Dominant Attribute Values

Alternatives	Score Value	Ranking of Alternatives
M_1	0.2916	1
M_2	0.2176	3

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

M_3	0.1057	4
M_4	0.1	5
M_5	0.2852	2

In this case also the alternatives are ranked based on the score values, the alternatives with higher score values are given first priorities. The ranking of the alternatives using the score values based on dominant attribute values facilitate ranking of best of the best alternatives. Now

Case (2a)

3.2.3 Ranking the alternatives based on equal weightage of recessive attribute values

In this case the alternatives are ranked based on the recessive attribute values by following the same procedure as in case (1a)

Table 3.11, 3.12 and 3.13 presents the evaluation matrix for the recessive attribute value Q11,Q23 and Q31.

Table 14: Evaluation matrix M_{R1} for the recessive attribute value Q11

		M_1	M_2	M_3	M_4	M_5
M_1		0	0.7	0	0.6	0
M_2		0.6	0	0.75	0	0.7
M_3		0.75	0.65	0	0	0.45
M_4		0.8	0	0.7	0	0.5
M_5		0	0.85	0	0.7	0

Table 15: Evaluation matrix M_{R2} for the recessive attribute value Q23

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.6	0	0.7	0
M_2	0.7	0	0.6	0	0.6
M_3	0.5	0.7	0	0	0.65
M_4	0.7	0	0.5	0	0.6
M_5	0	0.65	0	0.5	0

Table 16: Evaluation matrix M_{R3} for the recessive attribute value Q31

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.65	0	0.8	0
M_2	0.8	0	0.6	0	0.65
M_3	0.65	0.9	0	0	0.75
M_4	0.7	0	0.85	0	0.8
M_5	0	0.75	0	0.85	0

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

The combined matrix comprising the aggregate recessive attribute values with equal weightage (0.33 each) is present in Table 3.14

Table 17: Combined Matrix with equal weightage to Recessive Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.6435	0	0.693	0
M_2	0.726	0	0.6435	0	0.6435
M_3	0.627	0.7425	0	0	0.6105
M_4	0.726	0	0.6765	0	0.627
M_5	0	0.7425	0	0.6765	0

The plithogenic amicability degree is obtained using Eq.3.3

$$\frac{2}{pR_{ij}} = \frac{1}{u_{ij}} + \frac{1}{u_{ji}} \qquad \text{------------------------ (3.3)}$$

Table 18: Measure of Amicability Degree with equal weightage to Recessive Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.6823	0	0.7091	0
M_2	0.6823	0	0.6895	0	0.6895
M_3	0	0.6895	0	0	0
M_4	0.7091	0	0	0	0.6508
M_5	0	0.6895	0	0.6508	0

The score values of the alternatives are obtained using Eq.3.4.

$$F_R(Sg) = \frac{\sum_j pR_{ij}}{\sum_i \sum_j pR_{ij}} \qquad \text{--------------------- (3.4)}$$

The ranking of the alternatives based on the score values is presented in Table 3.16.

Table 19: Final Ranking of the Alternatives with equal weightage to Recessive Attribute Values

Alternatives	**Score Values**	**Ranking of Alternatives**
M_1	0.2034	4
M_2	0.3013	5
M_3	0.1008	1
M_4	0.1988	3
M_5	0.1959	2

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

Case (2b)

3.2.4 Ranking the alternatives based on unequal weightage of recessive attribute values

The combined matrix in Table 3.17 is also determined by considering unequal weightage to all the recessive attribute values as follows: W(Q12)=0.5, W(Q21)=0.25 W(Q33)=0.25

Table 20: Combined Matrix with unequal weightage to Recessive Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.6375	0	0.7	0
M_2	0.7	0	0.6375	0	0.6375
M_3	0.6	0.7375	0	0	0.625
M_4	0.725	0	0.6325	0	0.625
M_5	0	0.725	0	0.6375	0

The plithogenic amicability degree is obtained using Eq.3.3

Table 21: Measure of Amicability Degree with unequal weightage to Recessive Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.6673	0	0.7123	0
M_2	0.6673	0	0.6817	0	0.6784
M_3	0	0.6817	0	0	0
M_4	0.7123	0	0	0	0.6311
M_5	0	0.6784	0	0.6311	0

The score values of the alternatives are obtained using Eq.3.4. The ranking of the alternatives based on the score values is presented in Table 22.

Table 22: Final Ranking of the Alternatives with unequal weightage to Recessive Attribute Values

Alternatives	**Score Value**	**Ranking of Alternatives**
M_1	0.2046	4
M_2	0.3007	5
M_3	0.1011	1
M_4	0.1993	3
M_5	0.1947	2

The score values of the alternatives are generated using equation (4), and they are then ranked from highest to lowest based on their score values for the dominating attribute values. This kind of ranking facilitate in choosing best out of worst alternatives

The ranking results obtained in four cases namely case 1a,1b,2a,2b are compared in Table 3.20

Table 23: Comparison of Ranking Results

Alternatives	**Ranking with respect**	**Ranking with**	**Ranking with**	**Ranking with**

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

	to Dominant Attribute Values with equal weightage	respect to Dominant Attribute Values with unequal weightage	respect to Recessive Attribute Values with equal weightage	respect to Recessive Attribute Values with unequal weightage
M_1	1	1	4	4
M_2	3	3	5	5
M_3	4	4	1	1
M_4	5	5	3	3
M_5	2	2	2	2

Thus the Extended Plithogenic Sets facilitate in choosing the best of the best alternatives using dominant attribute values and best of the worst alternatives using recessive attribute values in decision making. In this case the alternative M5 is chosen to be best as in both the cases of dominant and recessive attribute values, the ranking is promising. The ranking results in Table 3.20 are more specific with respect to the decision maker's perception and the nature of the decision making situation. If the objective of the decision maker is to maximize the profit then the concern on the dominant attribute values will be very high. But at the same time if the decision maker is intended to minimize his loss, then he is more concerned on the recessive attribute values. In the former case M1 is preferred and in the latter M3 is preferred. Thus the ranking results in Table 3.20 are more specific and one can make choices of their own based on the constraints of profit maximization and loss minimization.

On other hand, it is not possible to obtain an overall ranking of the alternatives from the ranking results of Table 3.20 and henceforth the score values of the alternatives which are obtained under different cases are combined to arrive at global ranking. The score values obtained in case 1a and 2a are combined to determine the overall ranking of the alternatives (i.e. with respect to both dominant and recessive attribute values by considering equal weightages). Similarly, the score values obtained in case 1b and 2b are aggregated together to find the overall ranking of the alternatives (i.e. with respect to both dominant and recessive attribute values by considering unequal weightages). The overall ranking of the alternatives obtained from the deviations in the score values is presented in Table 3.21.

Table 24: Overall Ranking of the Alternatives

Alternatives	Deviations in the score values with respect to Dominant and Recessive Attribute Values with equal weightage	Ranking of the Alternatives	Deviations in the score values with respect to Dominant and Recessive Attribute Values with unequal weightage	Ranking of the Alternatives
M_1	0.0914	4	0.087	3
M_2	0.0829	2	0.0831	2
M_3	0.0057	1	0.0046	1
M_4	0.101	5	0.0993	5
M_5	0.0866	3	0.0905	4

From Table 3.21, the overall ranking of the alternatives is obtained by giving preference to the alternative with small differences between the score values. The score values obtained by considering dominant attribute values indicate positive score of the alternatives and the score values obtained using recessive attribute values indicate the negative scores of the alternatives. Therefore the differences between the positive and negative score values are considered in ranking the alternatives.

If equal weightages are considered then the ranking result obtained are M3 > M2 >M5>M1 > M4and if unequal weightages are considered then the ranking results obtained are M3 > M2 > M1> M5 >M4. Thus the ranking results differs accordingly to the assignment of weightages to the attribute values.

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

4. Applications of Extended Plithogenic Sociogram in Decision making on Food Packaging materials

In this section the extended plithogenic sociogram approach is applied in making decisions on food packaging materials. Food industries are supplying different varieties of food to the populace across this globe. The reputation of these industries is dependent on quality conservation. The aspect of quality and taste shall be conserved by using suitable food packaging materials. These industries must be cautious in making optimal selection of packaging materials and also must measure the potency of these materials using certain standard criteria or attributes. The packaging materials used in the food industry are available in a wide range of materials, forms, and colours that have distinct purposes in relation to maintaining the characteristics of the food item that they hold. In general the food industries are using different types of food packaging materials made up of metals, paper, plastic and glass. Table 4.1 presents the literature review of the nature of materials used in the Food packaging industries and the attributes considered

Table 25: State of Art of Research on the nature and attributes of the Food Packaging Materials

Author & Year	Nature of the material	Attributes to be Considered
Thakur.P et al., (2020) [51]	Food packaging colours for identification	Quality, storage, safety, reusable, easy to use and identification
Kenneth Marsh. ,et al (2007) [52]	Protection of food products and environmental issues	Shelf-life.
Alamri M.S [53]	Food safety perspective	Safety, quality,
Isabelle Maillet., et al (2013) [54]	Safety analysis and decision-making tool	Economic, safety, eco-system
Dikky Indrawan.,et al., (2019) [55]	Priority choice for ecofriendly bio-based food packaging	Quality , cost of material , cost of new investment , cost of human resource training , environmental friendly
Norton, V., et al.,(2022) [56]	Examining how consumers in the UK understand and view sustainable food packaging	Quality and shelf life
K. Cooksey., et al (2005) [57]	Antimicrobial packaging	Safety
M. Asgher., et al (2020) [58]	Bio-based food packaging materials	Safety.
Karina Petersen.,et al (1999) [59]	Bio-based food packaging materials	Safety, eco-system., quality
Michael G. K.,et al (2020) [60]	Preservation of food packaging technology	Quality ,safety, eco-system
Dele Raheem et al., (2012) [61]	Plastics and paper as food packaging materials	Quality ,safety, eco-system, shelf life
Ioannis S. A., et al (2004)[62]	Antimicrobial food packaging	Quality ,safety, eco-system
Jung H. Han.,et al (2005) [63]	Preservation of foods	Quality ,safety, eco-system
Md. Wadud Ahmed .,et al (2022) [64]	Current trends, applications, prospects and challenges	Quality and safety, shelf life
Hao Cheng .,et al (2022) [65]	Principles and preparations of food packaging materials	Maturity, quality, and safety.
Porta R.,et al(2020)[66]	Biopolymer based Food Packaging Materials	Cost, eco-friendly, storage and transport, shelf life
Saurabh Sid., et al (2021)[67]	Bio-sourced polymers in food packaging materials	Quality, storage, cost, health and environment

Based on the above Table 4.1, the following attributes and attribute values are considered for making optimal decisions are presented in Table 4.2

Table 26: Attribute & Attribute Values of Decision Making

Attribute	Attribute values

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

Price F1	Expensive (F11), affordable (F12), cheap (F13)
Resistance F2	High (F21), average (F22), low (F23)
Shell Life Longevity F3	Long (F31), moderate(F32), short(F33)
Eco-friendly F4	Reusable(F41), recyclable(F42) , non-biodegradable(F43)

4.1 Decision making based on Dominant Attribute Values

The dominant attribute values considered for decision making are Cheap (F13), High (F21), Long shell life (F31) and Reusable (F41). The preferential choice –making with respect to compatibility from the viewpoint of the experts is presented in Table 4.3

Table 27: Expert's opinion on Preferential Choice-Making over Compatibility

Alternatives/ Machines	**Preferential Choice-Making over Compatibility based on Dominant Attribute Values**	
	Expert-I	**Expert-II**
M_1	{M2(F13(0.5),F21(0.6),F31(0.7),F41(0.5)),M4(F13(0.6),F21(0.8),F31(0.6),F41(0.4))}	{M_3(F13(0.4),F21(0.5),F31(0.7),F41(0.7)),M5(F13(0.5),F21(0.6),F31(0.6), F41(0.8))}
M_2	M_1(F13(0.7),F21(0.6),F31(0.6), F41(0.4)), M_5(F13(0.8),F21(0.6),F31(0.5), F41(0.7))}	{M_3(F13(0.6),F21(0.4),F31(0.7),F41(0.8)), M4(F13(0.9),F21(0.8),F31(0.7), F41(0.6))}
M_3	{M1(F13(0.4),F21(0.5),F31(0.6),F41(0.7)),M2(F13(0.5),F21(0.6),F31(0.6),F41(0.8)),M4(F13(0.6),F21(0.8),F31(0.6), F41(0.5))}	M2(F13(0.6),F21(0.6),F31(0.7),F41(0.8)), M4(F13(0.4),F21(0.5),F31(0.6), F41(0.5))}
M_4	{M_2(F13(0.7),F21(0.5),F31(0.6),F41(0.8)),M3(F13(0.4),F21(0.6),F31(0.5), F41(0.7))}	{M1(F13(0.5),F21(0.6),F31(0.6),F41(0.8)), M3(F13(0.5),F21(0.5),F31(0.7),F41(0.6)),M5(F13(0.8),F21(0.8),F31(0.7), F41(0.4))}
M_5	{M1(F13(0.5),F21(0.5),F31(0.7),F41(0.7)),M2(F13(0.8),F21(0.6),F31(0.8),F41(0.4)),M3(F12(0.7),F23(0.7),F31(0.6), F41(0.5))}	{M1(F13(0.5),F21(0.4),F31(0.6),F41(0.7)), M4(F13(0.6),F21(0.8),F31(0.5), F41(0.5))}

Based on the procedural explained in section 3, the combined matrix considering equal weightage of 0.25 to each of the dominant attribute values is presented in Table 4.4

Table 28: Combined Matrix with equal weightage to Dominant Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.2875	0.285	0.3	0.3125
M_2	0.2875	0	0.3125	0.375	0.325
M_3	0.275	0.65	0	0.3125	0
M_4	0.3125	0.325	0.5625	0	0.3375
M_5	0.575	0.325	0.3125	0.3	0

The plithogenic amicability degree is obtained using Eq.3.1 and the values are presented in Table 4.5

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

Table 29:Measure of Amicability Degree with equal weightage to Dominant Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.2875	0.2799	0.3061	0.405
M_2	0.2875	0	0.4221	0.3482	0.325
M_3	0.2799	0.4221	0	0.4018	0
M_4	0.3061	0.3482	0.4018	0	0.3176
M_5	0.405	0.325	0	0.3176	0

The score values of the alternatives are obtained using Eq.3.2. The ranking of the alternatives based on the score values is presented in Table 4.6

Table 30: Final Ranking of the Alternatives with equal weightage to Dominant Attribute Values

Alternatives	**Score Value**	**Ranking of Alternatives**
M_1	0.2067	3
M_2	0.2235	1
M_3	0.1784	4
M_4	0.2221	2
M_5	0.1693	5

The above procedure is repeated with unequal weights to the dominant attribute values namely F13 = 0.4, F21 = 0.3, F31 = 0.2 and F41 = 0.1.

Table 31: Combined Matrix with unequal weightage to Dominant Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.285	0.26	0.32	0.29
M_2	0.31	0	0.29	0.4	0.335
M_3	0.25	0.61	0	0.565	0
M_4	0.29	0.315	0.53	0	0.37
M_5	0.535	0.35	0.33	0.315	0

The plithogenic amicability degree is obtained using Eq.3.1 and the values are presented in Table 4.8

Table 32: Measure of Amicability Degree with unequal weightage to Dominant Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.297	0.255	0.304	0.376
M_2	0.297	0	0.393	0.352	0.342
M_3	0.255	0.393	0	0.547	0

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

M_4	0.304	0.352	0.547	0	0.34
M_5	0.376	0.342	0	0.34	0

The score values of the alternatives are obtained using Eq.3.2. The ranking of the alternatives based on the score values is presented in Table 4.9

Table 33: Final Ranking of the Alternatives with unequal weightage to Dominant Attribute Values

Alternatives	Score Value	Ranking of Alternatives
M_1	0.1921	3
M_2	0.2158	2
M_3	0.1864	4
M_4	0.2406	1
M_5	0.165	5

4.2 Decision making based on Recessive Attribute Values

The recessive attributive values are Expensive (F11), low (F23), short (F33), non-biodegradable(F43). The opinion of the experts in the context of non-preferential choice making is presented in Table 4.10.

Table 34: Expert's opinion on Non-Preferential Choice-Making over Compatibility

Alternatives/ Machines	**Non-Preferential Choice-Making over Compatibility based on Recessive Attribute Values**	
	Expert-I	Expert-II
M_1	{M_3(F11(0.5),F23(0.4),F33(0.4),F43(0.5)), M_5((F11(0.6),F23(0.6),F33(0.4),F43(0.6)))}	{M2(F11(0.4),F23(0.7),F33(0.7),F43(0.6)), M_4((F11(0.4),F23(0.7),F33(0.6),F43(0.7)))}
M_2	{M3(F11(0.6),F23(0.4),F33(0.5),F43(0.5)), M_4((F11(0.7),F23(0.6),F33(0.5),F43(0.4)))}	{M1(F11(0.6),F23(0.6),F33(0.8),F43(0.6)), M_5((F11(0.7),F23(0.6),F33(0.5),F43(0.4)))}
M_3	{M2(F11(0.3),F23(0.6),F33(0.8),F43(0.6)), M_5((F11(0.5),F23(0.6),F33(0.7),F43(0.5)))}	{M1(F11(0.6),F23(0.9),F33(0.5),F43(0.4)), M_4((F11(0.5),F23(0.6),F33(0.7),F43(0.5)), M_5((F11(0.5),F23(0.5),F33(0.4),F43(0.5)))}
M_4	M2(F11(0.5),F23(0.4),F33(0.7),F43(0.4)), M_1((F11(0.6),F23(0.7),F33(0.7),F43(0.6)))}	{M3(F11(0.8),F23(0.6),F33(0.6),F43(0.7)), M_5((F11(0.7),F23(0.6),F33(0.7),F43(0.6)))}
M_5	M2(F11(0.5),F23(0.7),F33(0.8),F43(0.7)), M_4((F11(0.7),F23(0.4),F33(0.6),F43(0.5)), M_3((F11(0.5),F23(0.6),F33(0.7),F43(0.5)))}	{M1(F11(0.5),F23(0.7),F33(0.6),F43(0.4)), M_3((F11(0.6),F23(0.7),F33(04),F43(0.5)))}

Based on the procedural explained in section 3, the combined matrix considering equal weightage of 0.25 to each of the recessive attribute values is presented in Table 4.11

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

Table 35: Combined Matrix with equal weightage to Recessive Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.3	0.225	0.3	0.275
M_2	0.325	0	0.25	0.275	0.275
M_3	0.3	0.2875	0	0.2875	0.525
M_4	0.325	0.25	0.3375	0	0.325
M_5	0.275	0.3375	0.5625	0.275	0

The plithogenic amicability degree is obtained using Eq.3.3 and the values are presented in Table 4.12

Table 36: Measure of Amicability Degree with equal weightage to Recessive Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.312	0.2571	0.312	0.275
M_2	0.312	0	0.2674	0.2619	0.3031
M_3	0.2571	0.2674	0	0.3105	0.5431
M_4	0.312	0.2619	0.3105	0	0.2979
M_5	0.275	0.3031	0.5431	0.2979	0

The score values of the alternatives are obtained using Eq.3.4. The ranking of the alternatives based on the score values is presented in Table 4.13

Table 37: Final Ranking of the Alternatives with equal weightage to Recessive Attribute Values

Alternatives	Score Value	Ranking of Alternatives
M_1	0.1841	2
M_2	0.1822	1
M_3	0.2194	4
M_4	0.1883	3
M_5	0.226	5

The above procedure is repeated with unequal weights to the Recessive attribute values namely F11 = 0.5, F23 = 0.2, F33 = 0.2 and F43 = 0.1.

Table 38: Combined Matrix with unequal weightage to Recessive Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.27	0.23	0.109	0.28
M_2	0.32	0	0.265	0.305	0.305
M_3	0.31	0.245	0	0.28	0.52
M_4	0.32	0.26	0.36	0	0.335
M_5	0.275	0.31	0.565	0.3	0

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

The plithogenic amicability degree is obtained using Eq.3.3 and the values are presented in Table 4.15

Table 39: Measure of Amicability Degree with unequal weightage to Recessive Attribute Values

	M_1	M_2	M_3	M_4	M_5
M_1	0	0.293	0.264	0.162	0.278
M_2	0.293	0	0.255	0.28	0.307
M_3	0.264	0.255	0	0.315	0.541
M_4	0.162	0.28	0.315	0	0.317
M_5	0.278	0.307	0.541	0.317	0

The score values of the alternatives are obtained using Eq.3.4. The ranking of the alternatives based on the score values is presented in Table 4.16

Table 40: Final Ranking of the Alternatives with unequal weightage to Recessive Attribute Values

Alternatives	**Score Value**	**Ranking of Alternatives**
M_1	0.166	1
M_2	0.1884	3
M_3	0.2283	4
M_4	0.1783	2
M_5	0.2395	5

5. Discussion

In this section the ranking results obtained using the conditions of equal and unequal weightages to both of the dominant and recessive attribute values are compared and presented in Table 5.1

Table 41: Comparison of Ranking Results

Alternatives	**Ranking with respect to Dominant Attribute Values with equal weightage**	**Ranking with respect to Dominant Attribute Values with unequal weightage**	**Ranking with respect to Recessive Attribute Values with equal weightage**	**Ranking with respect to Recessive Attribute Values with unequal weightage**
M_1	3	3	2	1
M_2	1	2	1	3
M_3	4	4	4	4
M_4	2	1	3	2
M_5	5	5	5	5

Based on the dominant attribute values, the ranking results of the alternative packaging materials obtained is M4>M2>M1>M3>M5.In this case, the alternatives having greater score values are given high priorities. Based on the recessive attribute values, the ranking results of the alternative packaging materials obtained is M1>M4>M2>M3>M5. The ranking of the materials is based on the least scores of the alternatives. The ranking results shall also be interpreted as follows, based on the score values, the alternative M5 has given least preference then followed by M3, M2, M4 and M1. From both the ranking results, the decision makers can make decisions on giving preferences to the alternative materials based

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

on the suitability and non-suitability. If the decision makers have to make decisions based on feasibility then the ranking results obtained using dominant attribute values shall be considered, also if the decision has to be made based on infeasibility, then the ranking result obtained using recessive attribute values shall be taken into account. The first set of ranking results is centered on acceptance of the alternatives and the latter is based on denial of the alternatives. Also the second set of ranking facilitates us to decide the alternatives based on the principle of best out of worst. On the other hand, the student M5 has the lowest score, which indicates that the member is not much preferred as the attributes of M5 may not seem to be influential. It is very evident that the member M1 has the highest score, which represents the significance of the member M1 in the group and how his influencing attributes have made M2 more preferable.

Also the overall ranking of the alternatives shall be determined by considering the differences in the respective score values of dominant and recessive attribute values with equal and unequal weightages. The ranking results are presented in Table 5.2

Table 42: Overall Ranking of the Alternatives

Alternatives	Deviations in the score values with respect to Dominant and Recessive Attribute Values with equal weightage	Ranking of the Alternatives	Deviations in the score values with respect to Dominant and Recessive Attribute Values with unequal weightage	Ranking of the Alternatives
M_1	0.0226	1	0.0261	1
M_2	0.0413	4	0.0274	2
M_3	0.041	3	0.0419	3
M_4	0.0338	2	0.0623	4
M_5	0.0567	5	0.0745	5

From Table 5.2, it is observed that the alternative M1 gets the first preference and the alternative M5 gets the last preference in both the cases. The combined ranking results are also in consensus with the ranking results of Table 5.1. The decision maker can make use of the ranking results in both Table 5.1 and 5.2 based on the requirements of specificity or a comprehensive ranking.

6. Conclusion

This article explains the idea of developing of a more extensive form of Plithogenic sets. The conceptualization of 7-tuple plithogenic set plays a significant role in Plithogenic sociogram. The decision making based on Plithogenic sociogram with extended plithogenic sets is a novel approach of this research work. The consideration of dominant and recessive attribute values facilitates in obtaining the most feasible alternatives. The ranking results obtained using dominant attribute values are more closely associated with the intention of acceptance of the alternatives by the decision makers, on other hand the ranking results obtained using recessive attribute values are more closely associated with the intention of avoidance of the alternatives by the decision makers. On intensive analysis and comparison with the overall framework of multi-criteria decision making, the ranking approach based on dominant attribute values is in consensus with the concept of positive ideal solution and preferential choice making, also the ranking approach based on recessive attribute values is in consensus with the concept of negative ideal solution and non-preferential choice making. Thus the applications of extended plithogenic sets in Plithogenic sociogram discloses new approaches of making optimal decisions in specific to multi-criteria decision making methods.

Funding: “This research received no external funding”

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

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

References

[1] Smarandache F., lithogeny, Plithogenic Set, Logic, Probability and Statistics, preprint arXiv:1808.03948, Infinite Study, (2017)

[2] Florentin Smarandache., Plithogenic Set, an Extension of Crisp, Fuzzy, Intuitionistic Fuzzy, and Neutrosophic Sets – Revisited. Neutrosophic Sets and Systems, vol. 21,pp. 153-166.,(2018) https://doi.org/10.5281/zenodo.1408740

[3] Florentin Smarandache., Plithogenic Probability & Statistics are generalizations of MultiVariate Probability & Statistics., Neutrosophic Sets and Systems, Vol. 43, 2021.

[4] Sankar C., Sujatha R., Nagarajan D., Topsis by using Plithogenic set in COVID-19 Decision Making., International Journal of Neutrosophic Science (IJNS) Vol. 10, No. 2, PP. 116-125. (2020)

[5] Mohamed Abdel-Basset & Rehab, A novel plithogenic TOPSIS-CRITIC model for sustainable supply chain risk management, *Journal of Cleaner production*, 247. (2020).

[6] Nivetha Martin., Plithogenic SWARA-TOPSIS Decision Making on Food Processing Methods with Different Normalization Techniques, (2021). DOI: 10.5772/intechopen.100548

[7] Abdullah Ozcil., Aysegul Tus., Gulin Zeynep Oztas., Esra Aytac Adali & TayfunOztas., “The Novel Integrated Model of Plithogenic Sets and MAIRCA Method for MCDM problems”. International Conference on Intelligent and fuzzy systems.pp 733-741. (2020)

[8] Mohamed Grida, Rehab Mohamed and Abdel Nasser H. Zaied., A Novel Plithogenic MCDM Framework for Evaluating the Performance of IoT Based Supply Chain.” Neutrosophic sets and systems, Vol.33,1,pp-323-341,(2020).

[9] Shio Gai Quek , Ganeshsree Selvachandran , Florentin Smarandache J. Vimala , Son Hoang Le, Quang-Thinh Bui and Vassilis C. Gerogiannis., Entropy Measures for Plithogenic Sets and Applications in Multi-Attribute Decision Making., Mathematics, 8, 965, 2020; doi:10.3390/math8060965

[10] Mohamed Abdel-Basset, Rehab Mohamed, Florentin Smarandache, Mohamed Elhoseny., A New Decision-Making Model Based on Plithogenic Set for Supplier Selection., Computers, Materials & Continua., vol.66, no.3. (2021).

[11] Gomathy S., Nagarajan D., BroumiS., M. Lathamaheswari., Plithogenic sets and their application in decision making.,Neutrosophic Sets and Systems, Vol. 83, (2020) .

[12] Abdel-Basset M., Mohamed R., Zaied A. E. N. H, & Smarandache F., A Hybrid Plithogenic Decision-Making Approach with Quality Function Deployment for Selecting Supply Chain Sustainability Metrics. Symmetry, 11(7), 903, (2019).

[13] Priyadharshini S.P., Nirmala Irudayam F., A Novel approach of Refined Plithogenic Neutrosophic sets in Multi Criteria Decision Making., International Research Journal of Modernization in Engineering Technology and Science Volume:03/Issue:04/May-2021

[14] Priyadharshini S.P., Nirmala Irudayam F., A New Approach of Multi-Dimensional Single Valued Plithogenic Neutrosophic Set in Multi Criteria Decision Making., Neutrosophic Sets and Systems, Vol. 45, 2021

[15] Abdel-Basset M, Ding W, Mohamed , Metawa N., An integrated plithogenic MCDM approach for financial performance evaluation of manufacturing industries. Risk Management, (2020) .

[16] Abdel-Basset M, El-hoseny M, Gamal A, Smarandache F., A novel model for evaluation hospital medical care systems based on plithogenic sets. ArtifIntell Med 100:1–8,(2019). https://doi.org/10. 1016/j.artmed.2019.101710

[17] Smarandache, F. Extension of Soft set to Hypersoft Set, and then to Plithogenic Hypersoft Set, Neutrosophic set and Systems, 22, 168-170., (2018).

[18] Shawkat Alkhazaleh., Plithogenic Soft Set., Neutrosophic Sets and Systems, Vol. 33, 2020

[19] Shazia Rana , Madiha Qayyum , Muhammad Saeed , Florentin Smarandache , and Bakhtawar Ali Khan. Plithogenic Fuzzy Whole Hypersoft Set, Construction of Operators and their Application in Frequency Matrix Multi Attribute Decision Making Technique. Neutrosophic Sets and Systems, Vol. 28, 2019

[20] Dhivya E , ArokiaLancy A., Near Plithogenic Neutrosophic Hypersoft Heronian Mean Aggregation Operators and their Application in Multiple Attribute Decision Making., International Journal of Mechanical Engineering., Vol. 7 No. 8 August, 2022. ISSN: 0974-5823

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

[21] Muhammad Rayees Ahmad , Muhammad Saeed , Usman Afzal .,Miin-Shen Yang., A Novel MCDM Method Based on Plithogenic Hypersoft Sets under Fuzzy Neutrosophic Environment., Symmetry 2020, 12, 1855; doi:10.3390/sym12111855

[22] Shazia Rana, Muhammad Saeed, Midha Qayyum, Florentin Smarandache, Plithogenic Subjective Hyper-Super-Soft Matrices with New Definitions & Local, Global, Universal Subjective Ranking Model., International Journal of Neutrosophic Science (IJNS)., Vol. 6, No. 2, PP. 56-79.,(2020).

[23] Nivetha Martin, & Florentin Smarandache., Introduction to Combined Plithogenic Hypersoft Sets. Neutrosophic Sets and Systems, Vol. 35, 2020., https://doi.org/10.5281/zenodo.3951708

[24] Nivetha Martin, Florentin Smarandache and Said Broumi., COVID-19 Decision-Making Model using Extended Plithogenic Hypersoft Sets with Dual Dominant Attributes., International Journal of Neutrosophic Science (IJNS) Vol. 13, No. 2, PP. 75-86. (2021)

[25] Nivetha Martin and Florentin Smarandache ., Concentric Plithogenic Hypergraph based on Plithogenic Hypersoft sets – A Novel Outlook., Neutrosophic Sets and Systems, Vol. 33, 2020

[26] Vasantha WB, Ilanthenral K, Smarandache F. Plithogenic Graphs Bruxelles;vol. EuropaNova: 2020. . Available from: https://www.researchgate.net/publication/343769158_Plithogenic_Graphs

[27] Sultana F, Gulistan M, Ali M, Yaqoob N, Khan M, Rashid T, Ahmed T. A study of plithogenic graphs: applications in spreading coronavirus disease (COVID-19) globally. J Ambient Intell Humaniz Comput. 2022 Apr 4:1-21. doi: 10.1007/s12652-022-03772-6. Epub ahead of print. Erratum in: J Ambient Intell Humaniz Comput. 2022 Dec 6;:1. PMID: 35401852; PMCID: PMC8978528.

[28] Gayen S, Smarandache F, Jha S, Singh MK, Broumi S, and Kumar R ., Introduction to plithogenic subgroup. In: Neutrosophic graph theory and algorithm. p 209–233., (2019) IGIGlobal, Pennsylvania

[29] Nivetha Martin, FlorentinSmarandache and Said Broumi., PROMTHEE Plithogenic Pythagorean Hypergraphic Approach in Smart Materials Selection., International Journal of Neutrosophic Science (IJNS) Vol. 13, No. 1, PP. 52-60.,(2021)

[30] Prem Kumar Singh., Single-valued Plithogenic graph for handling multi-valued attribute data and its context., International Journal of Neutrosophic Science (IJNS) Vol. 15, No. 2, PP. 98-112. (2021).

[31] Prem Kumar Singh., Air Quality Index Analysis Using Single-Valued Neutrosophic Plithogenic Graph for Multi-Decision Process., International Journal of Neutrosophic Science (IJNS) Vol. 16, No. 1, PP. 28-41. (2021)

[32] Prem Kumar Singh., Dark data analysis using Intuitionistic Plithogenic graphs., International Journal of Neutrosophic Science (IJNS) Vol. 16, No. 2, PP. 80-100 (2021),

[33] Bharathi T, Leo S., A Study on Plithogenic Product Fuzzy Graphs with Application in Social network. Indian Journal of Science and Technology 14(40): 3051-3063. (2021) ., https://doi.org/10.17485/IJST/v14i40.1298

[34] Gayen S, Smarandache F, Jha S, Singh MK, Broumi S, Kumar R ., Introduction to plithogenic hypersoft subgroup. Neutrosophic Sets and Syst 33:208–233 (2020)

[35] Priyadharshini S.P., NirmalaIrudayam F., Plithogenic Neutrosophic set and Plithogenic Neutrosophic Topological Spaces (Submitted), 2021.

[36] Bhimraj Basumatary , Nijwm Wary , Muhammad Saeed and Muhammad Saqlain., On Some Properties of Plithogenic Neutrosophic Hypersoft Almost Topological Group., Neutrosophic Sets and Systems, Vol. 43, 2021

[37] Singh, P.K. , Complex Plithogenic Set. International Journal of Neutrosophic Sciences, 18, 57-72. (2022) .https://doi.org/10.54216/IJNS.180106

[38] Nivetha Martin, Florentin Smarandache, Priya R., Introduction to Plithogenic Sociogram with preference representations by Plithogenic Number., Journal of Fuzzy Extension & Application., 1(1). (2021).

[39] Noel Batista Hernández, Maikel Y. Leyva Vázque, Erick González Caballero, Lilia E. Valencia Cruzaty, Wilmer Ortega Chávez, and Florentin Smarandache., A New Method to Assess Entrepreneurship Competence in University Students Using Based on Plithogenic Numbers and SWOT Analysis., International Journal of Fuzzy Logic and Intelligent Systems 2021; 21(3): 280-292

[40] Raúl Comas Rodríguez , Sharon Dinarza Álvarez Gómez , Edgar Ramón Arredondo Domínguez , Lisenia Karina Baque Villanueva and Karina Pérez Teruel., A Novel Evaluative Method of the Subject “Education and Society” of the Autonomous University of the Andes, Ecuador, based on Plithogenic Numbers., Neutrosophic Sets and Systems ., Vol. 44, 2021

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

[41] Nivetha Martin and Florentin Smarandach., Plithogenic Cognitive Maps in Decision Making"., International Journal of Neutrosophic Science (IJNS) Vol. 9, No. 1, PP. 09-21. (2020)

[42] Nivetha Martin., Priya R., Smarandache F, New Plithogenic Sub Cognitive Maps Approach with Mediating Effects of Factors in Covid-19 Diagnostic Model, *Journal of Fuzzy Extension and Applications*, 2, 1-14, (2021).

[43] Priya R, and Nivetha Martin., Induced Plithogenic Cognitive Maps with Combined Connection Matrix to investigate the glitches of online learning system., Neutrosophic Sets and Systems, Vol. 43, 2021

[44] Sujatha R., Poomagal.S., KuppuswamiG., Said Broumi., An Analysis on Novel Corona Virus by a Plithogenic Approach to Fuzzy Cognitive Map., International Journal of Neutrosophic Science (IJNS) Vol. 11, No.2, PP. 62-75. (2020)

[45] Smarandache F, Physical Plithogenic sets., 71st Annual Gaseous Electronics conference, Session LW1, Oregon Convention Center Room, Portland, Oregon, USA, November 5-9, 2018;http://meetings.aps.org/Meeting/GEC18/Session/LW1.110

[46] Smarandache F., Aggregation plithogenic operators in physical fields. In: 71st annual meeting of the APS division of fluid dynamics. Bulletin of the American Physical Society, vol 63. (2018) https://meetings.aps.org/Meeting/DFD18/ Event/334150

[47] Bala George., Information Fusion Using Plithogenic Set and Logic., Acta scientific computer sciences Volume 2 Issue 8 August 2020.

[48] Walid Abdelfattah ., Variables Selection Procedure for the DEA Overall Efficiency Assessment Based Plithogenic Sets and Mathematical Programming., IJSRM Volume 10 Issue 05May 2022.

[49] Ariel Romero Fernández , Gustavo Álvarez Gómez , Sary del Rocío Álvarez Hernández , William Roberto ÁlvarezArboleda and Adonis Ricardo Rosales García., Selection of Investment Projects in a Plithogenic Environment., Neutrosophic Sets and Systems ,Vol. 44, 2021

[50] Fernández Villacrés Gustavo Eduardo., Fausto Alberto Viscaino Naranjo., Roberto Rolando López Domínguez.,Plithogenic Logic for Determination of Strategic Solutions for Ergonomic Occupational Health Risks., Neutrosophic Sets and Systems 44, 1. https://digitalrepository.unm.edu/nss_journal/ vol44/iss1/38

[51] Piyush Thakur A , Shivam Agarwal , Amisha Raghuvanshi , Rashmi Sharma., Role of Packaging in Different Stages of Decision Making., International Journal of Science and Research (IJSR) ISSN: 2319-7064 SJIF (2020): 7.803

[52] Kenneth Marsh., Betty Bugusu., Food Packaging—Roles, Materials, and Environmental Issues., Journal of Food Science., Vol. 72, Nr. 3, 2007. doi: 10.1111/j.1750-3841.2007.00301.x

[53] Alamri M.S., Akram A.A. Qasem, Abdellatif A. Mohamed, Shahzad Hussain, Mohamed A. Ibraheem, Ghalia Shamlan, Hesham A. Alqah, Ali S. Qasha., Food packaging's materials: A food safety perspective,Saudi Journal of Biological Sciences, Volume 28, Issue 8,2021,Pages 4490-4499,ISSN 1319-562X,https://doi.org/10.1016/j.sjbs.2021.04.047.

[54] Isabelle Maillet, Ariane Gaunand, Laurence Colinet, Safety analysis and decision making tools for the food-packaging sector. [Technical Report] auto-saisine. 2013, 14 p. ffhal-01605483

[55] Dikky Indrawan., Stevia Septian., Replacing Plastic: An Assessment of New Material for Food Production Package to Re-Engineer Packaging Industry Based on Multi-Criteria Analyses., Advances in Economics, Business and Management Research, Series volume number 141 Proceedings of the First ASEAN Business, Environment, and Technology Symposium (ABEATS 2019).

[56] Norton V., Waters C., Oloyede O.O., Lignou S., Exploring Consumers Understanding and Perception of Sustainable Food Packaging in the UK. Foods., 2022, 11, 3424. https://doi.org/10.3390/ foods11213424

[57] Cooksey K.., Effectiveness of antimicrobial food packaging materials., Food Additives and Contaminants, October 2005; 22(10): 980–987

[58] Muhammad Asgher, Sarmad Ahmad Qamar, Muhammad Bilal, Hafiz M.N., Iqbal,Bio-based active food packaging materials: Sustainable alternative to conventional petrochemical-based packaging materials,Food Research International,Volume 137,2020109625,ISSN 0963-9969, https://doi.org/10.1016/j.foodres.2020.109625.

[59] Karina Petersen, Per Vñggemose Nielsen, Grete Bertelsen, Mark Lawther, Mette B. Olsen, Nils H. Nilsson and Grith Mortensen., Potential of biobased materials for food packaging., Trends in Food Science & Technology 10 (1999).

[60] Michael G. Kontominas., Use of Alginates as Food Packaging Materials., Foods 2020, 9, 1440; doi:10.3390/foods9101440

[61] Dele Raheem., Application of plastics and paper as food packaging materials – An overview., Emir. J. Food Agric. 2012. 25 (3): 177-188 doi: 10.9755/ejfa.v25i3.11509

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023

[62] Ioannis S. Arvanitoyannis & Loulouda Bosnea (2004) Migration of Substances from Food Packaging Materials to Foods, Critical Reviews in Food Science and Nutrition, 44:2, 63-76, DOI: 10.1080/10408690490424621

[63] Jung H. Han., New technologies in food packaging: Overiew., Innovations in Food Packaging Food Science and Technology,2005, Pages 3-11

[64] Md. Wadud Ahmed , Md. Azizul Haque, Md. Mohibbullah , Md. Sirajul Islam Khan, Mohammed ., Ariful Islam , Md. Hasan Tarek Mondal , Raju Ahmmed., A review on active packaging for quality and safety of foods: Current trends, applications, prospects and challenge Food Packaging and Shelf Life., Volume 33, September 2022, 100913

[65] Hao Cheng , Hao Xu, David Julian.,McClements , Long Chen , Aiquan Jiao , Yaoqi Tian , Ming Miao, Zhengyu Jin., Recent advances in intelligent food packaging materials: Principles, preparation and applications., Food Chemistry., Volume 375, 1 May 2022, 131738

[66] Porta R, Sabbah M, Di Pierro P. Biopolymers as Food Packaging Materials. *International Journal of Molecular Sciences*. 2020; 21(14):4942. https://doi.org/10.3390/ijms21144942

[67] Saurabh Sid, Rahul S Mor, Anand Kishore, Vijay Singh Sharanagat., Bio-sourced polymers as alternatives to conventional food packaging materials: A review., Trends in Food Science & Technology., Volume 115, September 2021, Pages 87-104

Doi: https://doi.org/10.54216/IJNS.200401
Received: November 12, 2022 Accepted: March 05, 2023