Neutrosophic Systems with Applications, Vol. 10, 2023
https://doi.org/10.61356/j.nswa.2023.58

# A Novel Method of Decision Making Based on Plithogenic Contradictions

**Nivetha Martin [1,*], Florentin Smarandache [2] and Sudha S [3,4]**

[1] Department of Mathematics, Arul Anandar College (Autonomous), Karumathur, India; nivetha.martin710@gmail.com.
[2] University of New Mexico, Mathematics, Physics, and Natural Sciences Division 705 Gurley Ave., Gallup, NM 87301, USA; smarand@unm.edu.
[3] Research Scholar, Department of Mathematics, Madurai Kamaraj University, Madurai, India; sudhasikkanan@gmail.com.
[4] Assistant Professor, Department of Mathematics, SSM Institute of Engineering & Technology, Dindigul.

* Correspondence: nivetha.martin710@gmail.com.

**Abstract:** Plithogenic decision-making models are evolved integrating the Plithogenic modelling approach with various methods of multi-criteria decision-making (MCDM). The earlier Plithogenic based decision methods are primarily based on the degrees of appurtenance. This paper introduces a novel Plithogenic ranking genre of decision-making paradigm based on degrees of contradiction. The method of Decision Making on Plithogenic Contradictions (DMPC) developed in this research work is indigenous and unique as the modeling procedure doesn't resemble any of the decision methods. This simple and logical approach proposed in this paper is applied in making optimal decisions on supplier selection. The proposed contradiction based Plithogenic model shall be integrated with other decision methods and this will certainly create a breakthrough in framing contradictions based combined Plithogenic decision-making models.

**Keywords:** Plithogenic Sets; Plithogenic Contradiction; MCDM; Decision Making on Plithogenic Contradictions.

## 1. Introduction

The everlasting conflict of choosing the optimal alternatives satisfying all the criteria to the expected extent is motivating the researchers to develop new methods. This has led to the expansion of the theoretical aspects of decision-making with the development of scientific and algorithmic approaches to decision-making methods. The construction of any decision-making problem comprises certainly an elementary decision-making matrix with values matching the alternatives and criteria. The two prime objectives of the decision methods are to find the criterion weights and ranking of the alternatives. The decision-making methods are classified based on information availability, decision timeline, domain, level, structure, outcome, approach, and process.

The circumstances of making decisions are influenced by several factors affecting the deterministic nature of decision-making. The representations using crisp sets are replaced with the extension of fuzzy sets developed by Zadeh [1] to handle impreciseness and uncertainty. These fuzzy sets are further extended to intuitionistic sets [2] and neutrosophic sets to deal the situations of decision-making with hesitancy and indeterminacy. The decision-making methods developed in crisp sense are discussed by the researchers in the extended version of sets. However, these different representations of set are unified under one roof of Plithogeny by Smarandache [3] in the year 2018. The origin and development of Plithogenic sets has made novel plithogenic decision-making methods to evolve. Smarandache has contributed a lot to the field of Plithogeny, especially to the development of fundamental concepts of the Plithogenic sets [4-6]. Smarandache has also contributed

to Plithogenic algebraic structures [7-8]. Nivetha and Smarandache have together initialized the conceptualization of Plithogenic based hypergraphs and super hypergraphs [9-10].

A plithogenic set is basically a 5-tuple set that deals with attributes. This set comprises attribute values, degrees of appurtenance, and contradiction. The degrees of appurtenance decide the nature of the Plithogenic sets and it assumes any of the set representations such as crisp, fuzzy, intuitionistic, and neutrosophic. The Plithogenic decision-making methods primarily involve plithogenic operators to obtain a unified decision-making matrix based on the expert's opinion. The literature on Plithogenic based multi criteria decision making (MCDM) methods is limited. Some of the most commonly applied conventional decision-making methods are discussed in Plithogenic environment only with the inclusion of the Plithogenic operators of union and intersection and degrees of appurtenance. This has motivated the authors to develop a new genre of decision-making method based on the degrees of contradiction. The method of making decisions with a contradiction degree is proposed as a method of ranking the alternatives. This method is very simple in its formulation and the logical approach makes the method more rational.

The paper is organized as follows: section 2 sketches out the contributions in the domain of Plithogenic decision-making. Section 3 presents the proposed method of Decision Making on Plithogenic Contradictions. Section 4 applies the proposed method to the supplier selection problem. Section 5 discusses the results under different cases and section 6 concludes the work with future directions.

## 2. Literature review

The theory of Plithogeny is applied in MCDM integrating a wide range of different concepts of soft sets, Hypersoft sets, cognitive maps, hypergraphs, and many others. Plithogenic decision-making models are developed based on these concepts to design solutions to real-life problems. Plithogenic based MCDM are either the extensions or the generalizations of the existing mathematical concepts. The Plithogenic logic, probability statistics, and optimization assist in obtaining optimal solutions to decision-making problems. The contributions of researchers towards the formulation of Plithogenic decision-making models are presented in Table 1.

**Table 1.** Contributions of Plithogenic based decision making.

| Authors & Year | Plithogenic Decision Making Method | Domain of Application | Highlights of the contribution |
|---|---|---|---|
| Ozcil et al. [11] | MAIRCA | Green Supplier selection | • Minimization of the gap between ideal and empirical values<br>• Plithogenic aggregation operators |
| Abdel-Basset et al. 12] | VIKOR | Hospital medical care systems | • Plithogenic contradiction degree for dominant attribute |
| Abdel-Basset et al. [13] | QFD | Selecting supply chain sustainability | • Plithogenic aggregation operators |
| Rana et al. [14] | Plithogenic Hypersoft set, Plithogenic Whole Hypersoft set | Selecting faculty for the Engineering department | • Frequency matrix for final ranking |

| | | | |
|---|---|---|---|
| Abdel-Basset, & Mohamed, [15] | TOPSIS-CRITIC | Sustainable supply chain risk management | • Plithogenic aggregation operators |
| Abdel-Basset et al. [16] | BWM | Supply chain problem | • Plithogenic aggregation operators |
| Abdel-Basset et al. [17] | AHP,VIKOR, TOPSIS | Financial performance evaluation in manufacturing industries | • Plithogenic aggregation operators |
| Gómez et al. [18] | VIKOR | Pedagogical performance. | • Plithogenic aggregation operators |
| Grida et al. [19] | VIKOR,BWM | IoT based supply chain | • Plithogenic aggregation operators |
| Abdel-Basset et al. [20] | MABAC; BWM | Supplier selection | • Plithogenic aggregation |
| Ahmad et al. [21] | PHSS based TOPSIS | Parking spot choice problem | • Plithogenic aggregation |
| Smarandache, &Martin [22] | Plithogenic n-super hypergraph, Dominant enveloping vertex | E-learning system of education (Work from Home During Covid-19) | • Classification of Dominant Enveloping Vertex<br>• Plithogenic Connectors |
| Gomathy et al. [23] | Plithogenic operator laws (fuzzy tnorm & tconorm) | Medical field | • Plithogenic aggregate operators |
| Martin et al. [24] | Plithogenic sociogram & Plithogenic number | Food processing industry | • Preferential ordering based on attributes |
| Öztaş et al. [25] | Plirhogeny, DEA | Tourist travelers performance (Accommodation for touristic travelers) | • Plithogenic aggregation operations |
| Korucuk et al. [26] | CRITIC | logistics sector | • Plithogenic aggregation operations |
| Sujatha, et al. [27] | FCM, Plithogenic operators | Corona virus (Covid-19) | • Plithogenic aggregation of weights |
| Martin et al. [28] | PHS,DM | Covid- 19 | • Extended combined plithogenic hypersoft sets |

| | | | |
|---|---|---|---|
| Hernández et al. [29] | Plithogenic logic, SWOT | Entrepreneurship competence in university students | • Plithogenic aggregation operators |
| Martin et al. [30] | PSCM | Factors in COVID-19 diagnostic model | • Degree of contradiction with respect to the factors |
| Ulutaş et al. [31] | PIPRECIA | Prioritization of logistics sector | • Plithogenic aggregation operators |
| Ulutaş et al. [32] | SWARA | Logistics sector | • Plithogenic aggregation operators |
| Singh. [33] | Plithogenic graph; Plithogenic set | Olympic Players performance | • Plithogenic aggregation operators |
| Ansari & Kant. [34] | AHP | Supply chain | • Plithogenic aggregation operators |
| Martin et al. [35] | PROMTHEE | Smart materials selection | • Plithogenic aggregation operators |
| Singh [36] | Plithogenic graphs | Dark data analysis (Performance of players in crickets) | • Conflict situation |
| Singh [37] | Plithogenic graphs | Air Quality Index Analysis(Impact on human health) | • Single-valued Neutrosophic Plithogenic data visualization |
| Priyadharshini & Irudayam [38] | MCDM | Agriculture field | • Plithogenic aggregate operators |
| Rodríguez et al. [39] | Plithogenic number, MCDM | Education and Society | • Representations using Plithogenic number |
| Priya & Martin [40] | PCM, IPCM, CCM | online learning system | • Plithogenic sets in determining the association between the factors |
| Fernández et al. [41] | AHP, TOPSIS | Selection of Investment Projects | • Plithogenic aggregate operators |
| Castro Sánchez et al. [42] | Plithogenic logics | Educational Development | • Plithogenic aggregate operators |
| Priyadharshini & Irudayam [43] | RPNS | Candidate's selection in interview. | • RPNS Operators<br>• Correlation measures and its properties |
| Bharathi & Leo [44] | PPfuzzy graph | Social Network | • To discover the network's most outgoing, gregarious, powerful, and key figures. |

| | | | |
|---|---|---|---|
| Villacrés et al. [45] | AHP | Ergonomic Occupational Health Risks for teachers | • Instant solutions |
| Moncayo et al. [46] | SWOT, Plithogeny | Ecuadorian Hospital environment | • Plithogenic operators |
| Pai & Prabhu Gaonkar [47] | Plithogenic set | Risk Assessment due to accident | • Assessing risk and ranking of the criteria in a complex system |
| Romero et al. [48] | AHP,TOPSIS | Investment Projects selection problem | • Plithogenic aggregate operators |
| Antonio et al. [49] | Plithogenic logic | Electronic payment methods/Mechanism | • Plithogenic aggregate operators |
| Sultana et al. [50] | Plithogenic graphs | Spreading coronavirus disease (COVID-19) | • Plithogenic aggregate operators |
| Ahmad & Afzal [51] | PDM,PHSS,PSM | Mathematical modeling and AI (COVID-19 suspect) | • Plithogenic aggregate operators |
| Martin, N [52] | SWARA-TOPSIS | Food Processing Methods | • Plithogenic operators |
| Liang et al. [53] | CRITIC, Game theory, TOPSIS-GRA | Air traffic flow problem | • Plithogenic aggregation |
| Abdelfattah, W. [54] | DEA | University in Saudi Arabia | • Plithogenic aggregation |
| Wang et al. [55] | COPRAS, PNRN | Sustainable Financing Enterprise selection | • Extended Similarity Measures |
| Sudha & Martin [56] | BWM | Teaching methods | • Plithogenic Pythagorean set. |
| Sudha., Martin, &Broumi [57] | CRITIC-MAIRCA | Livestock Feeding Stuff problem | • Plithogenic aggregation |
| Ulutaş, & Topal [58] | PIPRECIA | Renewable energy industry | • Plithogenic aggregation |
| Seby, & Ravi [59] | Plithogeny | Supply chain | • Plithogenic aggregation |
| Priya,, Martin, & Kishore [60] | Plithogeny | Human's cognitive domain | • Contradiction degree in PCM |
| Zuñiga et al. [61] | Plithogenic number | Classifications of clays | • Representations using Plithogenic numbers |
| Tayal et al. [62] | TOPSIS, WSM | Business | • Plithogenic aggregation |

| | | | |
|---|---|---|---|
| Wang et al. [63] | VIKOR | Supply Chain Financial risk evaluation | • Probabilistic Linguistic MAGDM |
| Sudha, & Martin [64] | PIPRECIA, AHP | Logistics selection sector | • Plithogenic Operators |

In the above mentioned Plithogeny based decision-making methods, the following research gaps are identified.

- The plithogenic operators based on degree of appurtenance are widely applied and only in few instances the contradiction degree is used.
- The plithogenic oriented decision-making methods lack the use of the aspect of contradiction degree in handling the alternatives and criteria.

Hence this research work designs a decision-making method purely based on the contradiction degrees with respect to the dominant attribute value of the alternatives. The novel attributes of this paper are as follows:

- A distinctive decision making approach based on contradictions degree.
- Simple and compatible method of finding the optimal alternatives.
- Flexible method which accommodates several alternatives and criteria.

## 3. Proposed Method of Decision making based on Plithogenic Contradictions

This section consists of the steps involved in the method of Decision Making on Plithogenic Contradictions (DMPC). The elementary steps of this method are similar to the general working principle of an MCDM method. Figure 1 presents the overall framework of the proposed method of DMPC.

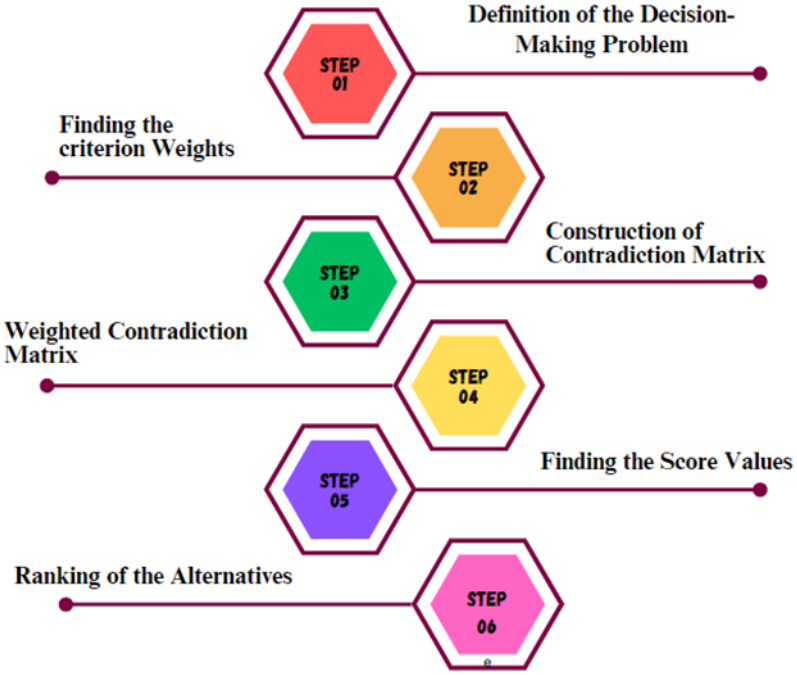


**Figure 1.** Overall framework of DMPC.

***Step 1:*** *Definition of the decision-making problem*

It is the initial step in which the problem is well defined with alternatives and criteria. The criteria are classified into benefit and non-benefit based on the nature of the problem. Each of the criterion has

sub-values. The decision making matrix with initial values is constructed especially with linguistic variables.

$$D_L = \begin{bmatrix} x_{L11} & \cdots & x_{L1n} \\ \vdots & \ddots & \vdots \\ x_{Lm1} & \cdots & x_{Lmn} \end{bmatrix}$$

The decision making matrix is with m alternatives and n criteria.

***Step 2:*** *Finding the Criterion Weights*

The criterion weights say Wk are determined using any of the methods. Each of the criterion has criterion values say Cki.

***Step 3:*** *Construction of contradiction matrix*

The dominant criterion value say CkD among the criterion values of each criteria is identified. The contradiction degree among the criterion values is determined. Based on the contradiction degree, the contradiction matrix is constructed with contradiction degrees pertaining to the dominant criterion value with respect to the values assumed by each alternative with respect to the criterion value in the initial matrix.

$$C_D = \begin{bmatrix} c_{D11} & \cdots & c_{D1n} \\ \vdots & \ddots & \vdots \\ c_{Dm1} & \cdots & c_{Dmn} \end{bmatrix}$$

***Step 4:*** *Weighted contradiction matrix*

The weighted contradiction matrix $[WC_D]$is obtained by multiplying the criterion weights with the values of contradiction matrix.

***Step 5:*** *Finding the score values*

The score values of each of the alternative with respect to both benefit and cost criteria say BSj and CSh is first calculated. The difference between the values is determined, say BSj - CSh = Df

***Step 6:*** *Ranking of the alternatives*

The alternatives are ranked based on the difference values Df. The alternative with maximum difference value is ranked first and so on.

## 4. Application of DMPC in supplier selection

In this section, a decision-making problem is solved using the proposed method of DMPC. Let us consider a logistic supplier selection problem with five alternatives and four criteria say C1 – Price, C2 – Time span of delivery, C3 – Flexibility, and C4 – Reliability.

The criteria C1 and C2 are considered to be cost criteria and the criteria C3 and C4 are considered as benefit criteria.

Each criteria presumed to be the attribute possess the attribute values of {L, M, H} i.e. {Low, Moderate, High}.

For the cost criteria, the dominant attribute value is certainly LOW & for the benefit criteria it is HIGH.

Contradiction degree with respect to dominant attribute value (LOW) of the cost criteria (C1 & C2).

C(L,L) = 0
C(L,M) = 1/3
C(L,H) = 2/3

Contradiction degree with respect to dominant attribute value (HIGH) of the benefit criteria.

C(H,H) = 0
C(H,M) = 1/3
C(H,L) = 2/3
C(M,M) =0

The initial decision making matrix with linguistic values is presented in Table 2.

**Table 2.** Initial decision making matrix.

| Alternatives /Criteria | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| | Cost Criteria | | Benefit Criteria | |
| A1 | L | H | L | M |
| A2 | H | M | L | M |
| A3 | M | L | H | M |
| A4 | L | L | M | H |
| A5 | L | H | M | L |

The assumed criterion weights and the dominant attribute value with respect to each of criterion are presented as follows in Table 3.

**Table 3.** Decision matrix with criterion description.

| Alternatives/ Criteria | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| | Cost Criteria | | Benefit Criteria | |
| | 0.35 | 0.25 | 0.20 | 0.20 |
| A1 | L | H | L | M |
| A2 | H | M | L | M |
| A3 | M | L | H | M |
| A4 | L | L | M | H |
| A5 | L | H | M | L |
| Dominant Value | L | L | H | H |

The contradiction matrix with the contradiction degree of each criterion values with respect to the dominant criterion value is presented as follows in Table 4 using step 3.

**Table 4.** Contradiction matrix.

| Alternatives/ Criteria | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| | Cost Criteria | | Benefit Criteria | |
| | 0.35 | 0.25 | 0.20 | 0.20 |
| A1 | 0 | 2/3 | 2/3 | 1/3 |
| A2 | 2/3 | 1/3 | 2/3 | 1/3 |
| A3 | 1/3 | 0 | 0 | 1/3 |
| A4 | 0 | 0 | 1/3 | 0 |
| A5 | 0 | 2/3 | 1/3 | 2/3 |

The weighted contradiction matrix is computed using step 4 as follows in Table 5.

**Table 5.** Weighted contradiction matrix.

| Alternatives /Criteria | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| | Cost Criteria | | Benefit Criteria | |
| A1 | 0.00 | 0.17 | 0.13 | 0.07 |
| A2 | 0.23 | 0.08 | 0.13 | 0.07 |
| A3 | 0.12 | 0.00 | 0.00 | 0.07 |
| A4 | 0.00 | 0.00 | 0.07 | 0.00 |
| A5 | 0.00 | 0.17 | 0.07 | 0.13 |

The score values of the benefit and cost criteria with respect to each alternative are calculated as presented in Table 6.

**Table 6.** Score values of criteria.

| Alternatives | Cost Criteria | Benefit Criteria |
|---|---|---|
| A1 | 0.17 | 0.20 |
| A2 | 0.31 | 0.20 |
| A3 | 0.12 | 0.07 |
| A4 | 0.00 | 0.07 |
| A5 | 0.17 | 0.20 |

The differences between the benefit and the cost criteria score values are presented in Table 7.

**Table 7.** Difference in score values.

| Alternatives | Differences in the score values |
|---|---|
| A1 | 0.03 |
| A2 | -0.11 |
| A3 | -0.05 |
| A4 | 0.07 |
| A5 | 0.03 |

Based on the difference values the alternatives are ranked as follows as in Table 8.

**Table 8.** Ranking of the alternatives.

| Alternatives | Ranking |
|---|---|
| A1 | 2 |
| A2 | 4 |
| A3 | 3 |
| A4 | 1 |
| A5 | 2 |

## 5. Discussion

The above ranking of the alternatives is obtained with assumed criterion weights. The same ranking procedure based on contradictions is repeated with different criterion weights obtained using various methods such as the Analytical Hierarchy Process (AHP), Entropy, and the method of CRITIC (CRiteria Importance through Intercriteria Correlation). Table 9 and Figure 2 represent the rankings of the alternatives using different criterion weights.

**Table 9.** Ranking of alternatives based on different criterion weights.

| Alternatives | Rankings based on diverse criterion weights | | |
|---|---|---|---|
| | AHP | CRITIC | Entropy |
| A1 | 2 | 2 | 2 |
| A2 | 5 | 4 | 5 |
| A3 | 4 | 5 | 4 |
| A4 | 1 | 1 | 1 |
| A5 | 3 | 3 | 3 |

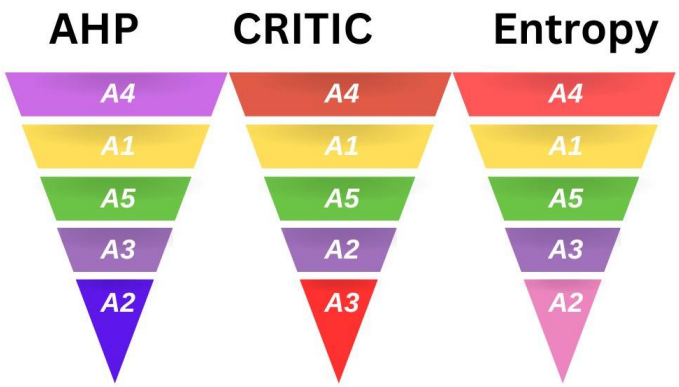


**Figure 2.** Graphical representation of diverse ranking of the alternatives.

## 6. Conclusions

This research work proposes a new genre of Plithogenic based decision-making method based on contradictions. The proposed method stands distinct in comparison with other methods as it streamlines a new modality of making optimal decisions. This method will definitely lessen the hurdles in choosing the alternatives based on cost and benefit criteria. The ranking obtained using the Plithogenic method based on contradictions is compared with different criterion weights. This method shall be dealt with extended Plithogenic sets. Also, the method of Plithogenic Cognitive Maps shall be associated with the proposed method as a means of developing several hybrid decision-making methods. This method is highly adaptable and flexible in nature and hence it shall be blended with other decision-making models to evolve new hybrid decision-making systems.

**Acknowledgments**

The author is grateful to the editorial and reviewers, as well as the correspondent author, who offered assistance in the form of advice, assessment, and checking during the study period.

**Data availability**

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

**Conflict of interest**

The authors declare that there is no conflict of interest in the research.

**Ethical approval**

This article does not contain any studies with human participants or animals performed by any of the authors.

## References

1. Zadeh L. A.; Fuzzy sets, *Information and Control*, 1965, 8,338-353.
2. Atanassov, K. T.; Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, 1986, 20(1), 87–96. https://doi.org/10.1016/S0165-0114(86)80034-3
3. Florentin Smarandache.; Plithogenic Set, an Extension of Crisp, Fuzzy, Intuitionistic Fuzzy, and Neutrosophic Sets – Revisited. *Neutrosophic Sets and Systems*, 2018, vol. 21, pp. 153-166. https://doi.org/10.5281/zenodo.1408740
4. Florentin Smarandache: Plithogenic Set, an Extension of Crisp, Fuzzy, Intuitionistic Fuzzy, and Neutrosophic Sets - Revisited. *Neutrosophic Sets and Systems*, Vol. 21, 2018, 153-166.

5. Florentin Smarandache: Extension of Soft Set to Hypersoft Set, and then to Plithogenic Hypersoft Set. *Neutrosophic Sets and Systems*, Vol. 22, 2018, 168-170.
6. Florentin Smarandache: Conjunto plitogenico, una extension de los conjuntos crisp, difusos, conjuntos difusos intuicionistas y neutrosoficos revisitado. *Neutrosophic Computing and Machine Learning*, Vol. 3, 2018, 1-19.
7. Florentin Smarandache, Introduction to the Symbolic Plithogenic Algebraic Structures (revisited), *Neutrosophic Sets and Systems*2022., Vol. 53,
8. Florentin Smarandache, An Overview of Plithogenic Set and Symbolic Plithogenic Algebraic Structures (Review Paper), J. *Fuzzy. Ext.Appl.* Vol. 4, No. 1 (2023) 48–55, http://fs.unm.edu/P/Plithogeny-JFEA.pdf
9. Nivetha Martin, Florentin Smarandache: Concentric Plithogenic Hypergraph based on Plithogenic Hypersoft sets - A Novel Outlook. Neutrosophic Sets and Systems, Vol. 33, 2020, 78-91.
10. Florentin Smarandache, Nivetha Martin: Plithogenic n-Super Hypergraph in Novel Multi-Attribute Decision Making. *International Journal of Neutrosophic Science* (IJNS) Vol. 7, No. 1, 2020, 8-30.
11. Özçil, A., Tuş, A., Öztaş, G. Z., Adalı, E. A., & Öztaş, T. The novel integrated model of plithogenic sets and MAIRCA method for MCDM problems. *In International conference on intelligent and fuzzy systems* (pp. 733-741). (2020, July). Cham: Springer International Publishing.
12. Abdel-Basset, M., El-Hoseny, M., Gamal, A., & Smarandache, F. A novel model for evaluation Hospital medical care systems based on plithogenic sets. *Artificial intelligence in medicine*, (2019), 100, 101710.
13. 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*, (2019). 11(7), 903.
14. Rana, S., Qayyum, M., Saeed, M., Smarandache, F., & Khan, B. A. Plithogenic fuzzy whole hypersoft set, construction of operators and their application in frequency matrix multi attribute decision making technique. *Infinite Study*. (2019).
15. Abdel-Basset, M., & Mohamed, R. A novel plithogenic TOPSIS-CRITIC model for sustainable supply chain risk management. *Journal of Cleaner Production*, (2020). 247, 119586.
16. Abdel-Basset, M., Mohamed, R., Zaied, A. E. N. H., Gamal, A., & Smarandache, F. Solving the supply chain problem using the best-worst method based on a novel Plithogenic model. *In Optimization theory based on neutrosophic and plithogenic sets* (pp. 1-19). (2020). Academic Press.
17. Abdel-Basset, M., Ding, W., Mohamed, R., & Metawa, N. An integrated plithogenic MCDM approach for financial performance evaluation of manufacturing industries. *Risk management*, (2020). 22, 192-218.
18. Gómez, G. Á., Moya, J. V., Ricardo, J. E., & Sánchez, C. B. V. Evaluating Strategies of Continuing Education for Academics Supported in the Pedagogical Model and Based on Plithogenic Sets (Vol. 37). (2020). *Infinite Study*.
19. Grida, M., Mohamed, R., & Zaid, A. H. A novel plithogenic MCDM framework for evaluating the performance of IoT based supply chain. *Neutrosophic sets and systems*, (2020). 33(1), 323-341.
20. Abdel-Basset, M., Mohamed, R., Smarandache, F., & Elhoseny, M. A new decision-making model based on plithogenic set for supplier selection. *Infinite Study*. (2020).
21. Ahmad, M. R., Saeed, M., Afzal, U., & Yang, M. S. A novel MCDM method based on plithogenic hypersoft sets under fuzzy neutrosophic environment. *Symmetry*, (2020). 12(11), 1855
22. Smarandache, F., & Martin, N. Plithogenic n-super hypergraph in novel multi-attribute decision making. *Infinite Study*. (2020).
23. Gomathy, S., Nagarajan, D., Broumi, S., & Lathamaheswari, M. Plithogenic sets and their application in decision making. *Infinite Study*. (2020).
24. Martin, N., Smarandache, F., & Priya, R. Introduction to Plithogenic Sociogram with preference representations by Plithogenic Number. *Infinite Study*. (2020).
25. Öztaş, G. Z., Adalı, E. A., Tuş, A., Öztaş, T., & Özçil, A. An Alternative Approach for Performance Evaluation: Plithogenic Sets and DEA. *In International Conference on Intelligent and Fuzzy Systems* (pp. 742-749). (2020, July).Cham: Springer International Publishing.
26. Korucuk, S., Demir, E., Karamasa, C., & Stević, Ž. Determining the dimensions of the innovation ability in logistics sector by using plithogenic-critic method: An application in Sakarya Province. *International Review,* (1-2), (2020). 119-127

27. Sujatha, R., Poomagal, S., Kuppuswami, G., & Broumi, S. An Analysis on Novel Corona Virus by a Plithogenic Approach to Fuzzy Cognitive Map. *Infinite Study*. (2020).
28. Martin, N., Smarandache, F., & Broumi, S. Covid-19 decision-making model using extended plithogenic hypersoft sets with dual dominant attributes. *International journal of neutrosophic science*, 13(2), (2021). 75-86.
29. Hernández, N. B., Vázquez, M. Y. L., Caballero, E. G., Cruzaty, L. E. V., Chávez, W. O., & Smarandache, F. 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*, 21(3), (2021). 280-292.
30. Martin, N., Priya, R., & Smarandache, F. New Plithogenic sub cognitive maps approach with mediating effects of factors in COVID-19 diagnostic model. *Infinite Study*. (2021).
31. Ulutaş, A., Topal, A., Karabasevic, D., Stanujkic, D., Popovic, G., & Smarandache, F. Prioritization of logistics risks with plithogenic PIPRECIA method. *In International Conference on Intelligent and Fuzzy Systems* (pp. 663-670). (2021, August). Cham: Springer International Publishing
32. Ulutaş, A., Meidute-Kavaliauskiene, I., Topal, A., & Demir, E. Assessment of collaboration-based and non-collaboration-based logistics risks with plithogenic SWARA method. *Logistics*, (2021). 5(4), 82.
33. Singh, P. K. Single-valued Plithogenic graph for handling multi-valued attribute data and its context. *Int. J. Neutrosophic Sci*, 15, (2021). 98-112.
34. Ansari, Z. N., & Kant, R. A plithogenic based neutrosophic analytic hierarchy process framework to analyse the barriers hindering adoption of eco-innovation practices in supply chain. *International Journal of Sustainable Engineering*, 14(6), (2021). 1509-1524
35. Martin, N., Smarandache, F., & Broumi, S. PROMTHEE plithogenic pythagorean hypergraphic approach in smart materials selection. *Int J Neutrosophic Sci*, 13, (2021). 52-60.
36. Singh, P. K. Dark data analysis using intuitionistic plithogenic graphs. *International Journal of Neutrosophic Sciences*, 16(2), (2021). 80-100.
37. Singh, P. K. Air Quality Index Analysis Using Single-Valued Neutrosophic Plithogenic Graph for Multi-Decision Process. *International Journal of Neutrosophic Science* (IJNS), 16(1). (2021).
38. Priyadharshini, S. P., & Irudayam, F. N. A New Approach of Multi-Dimensional Single Valued Plithogenic Neutrosophic Set in Multi Criteria Decision Making. *Infinite Study*. (2021).
39. Rodríguez, R. C., Gómez, S. D. Á., Domínguez, E. R. A., Villanueva, L. K. B., & Terue, K. P. A Novel Evaluative Method of the Subject "Education and Society" of the Autonomous University of the Andes, Ecuador, based on Plithogenic Numbers. *Infinite Study*. (2021).
40. Priya, R., & Martin, N. Induced Plithogenic Cognitive Maps with Combined Connection Matrix to investigate the glitches of online learning system. *Infinite Study*. (2021).
41. Fernández, A. R., Gómez, G. Á., Hernández, S. D. R. Á., Arboleda, W. R. Á., & García, A. R. R. Selection of Investment Projects in a Plithogenic Environment. *Infinite Study*. (2021).
42. Castro Sánchez, F., Almeida Blacio, J. H., Flores Bracho, M. G., Andrade Santamaria, D. R., & Sánchez Casanova, R. Neutrosophic and Plithogenic Statistical Analysis in Educational Development. *Neutrosophic Sets and Systems*, 44(1), (2021). 26.
43. Priyadharshini, S. P., & Irudayam, F. N. A novel approach of refined plithogenic neutrosophic sets in multi criteria decision making. *Infinite Study*. (2021).
44. Bharathi, T., & Leo, S. A Study on Plithogenic Product Fuzzy Graphs with Application in Social network. *Indian Journal of Science and Technology*, 14(40), (2021). 3051-3063
45. Villacrés, G. E. F., Naranjo, F. A. V., & López, R. R. L. Plithogenic Logic for Determination of Strategic Solutions for Ergonomic Occupational Health Risks. *Infinite Study*. (2021).
46. Moncayo, M. F. C., Freire, L. E., Flores, L. C. G., & Delgado, J. L. G. Definition of Strategies in Ecuadorian Hospitals in a Plithogenic Environment. *Infinite Study*. (2021).
47. Pai, S. P., & Prabhu Gaonkar, R. S. Risk Assessment Using Evidential Reasoning in Plithogenic Environment. In Current Advances in Mechanical Engineering: *Select Proceedings of ICRAMERD* 2020 (2021). (pp. 949-962). Springer Singapore.

48. Romero Fernández, A., Álvarez Gómez, G., Álvarez Hernández, S. D. R., Álvarez Arboleda, W. R., & Rosales García, A. R. Selection of Investment Projects in a Plithogenic Environment. *Neutrosophic Sets and Systems,* 44(1), (2021). 30.
49. Antonio, L. O. L., Alberto, V. N. F., Toapanta, C., Vinicio, W., Naranjo, B., & Patricio, F. Electronic Payments in Decentralized Autonomous Municipal Governments of Ecuador. Decision Making through Plithogenic Logic. *Infinite Study*. (2021).
50. 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. *Journal of ambient intelligence and humanized computing*, 1-21(2022).
51. Ahmad, M. R., & Afzal, U. Mathematical modeling and AI based decision making for COVID-19 suspects backed by novel distance and similarity measures on plithogenic hypersoft sets. *Artificial Intelligence in Medicine*, 132, (2022). 102390
52. Martin, N. Plithogenic SWARA-TOPSIS Decision Making on Food Processing Methods with Different Normalization Techniques. *Advances in Decision Making, 69-78*. (2022).
53. Liang, B., Han, S., Li, W., Han, Y., Liu, F., Zhang, Y., & Lin, C. Plithogenic multi-criteria decision making approach on airspace planning scheme evaluation based on ATC-flight real-time simulation. IET *Intelligent Transport Systems*, 16(11), (2022). 1471-1488.
54. Abdelfattah, W. Variables Selection Procedure for the DEA Overall Efficiency Assessment Based Plithogenic Sets and Mathematical Programming. (2022).
55. Wang, P., Lin, Y., & Wang, Z. An Integrated Decision-Making Model Based on Plithogenic-Neutrosophic Rough Number for Sustainable Financing Enterprise Selection. *Sustainability*, 14(19), (2022). 12473.
56. Sudha, S., & Martin, N. Comparison of plithogenic and neutrosophic approaches in decision making via best–worst method. *In AIP Conference Proceedings* (Vol. 2516, No. 1). (2022, November). *AIP Publishing*
57. Sudha, S., Martin, N., & Broumi, S. Plithogenic CRITIC-MAIRCA Ranking of Feasible Livestock Feeding Stuffs. *International Journal of Neutrosophic Science* (IJNS), 18(4). (2022).
58. Ulutaş, A., & Topal, AEvaluation of the criteria used in the selection of renewable energy sources with the plithogenic PIPRECIA method. In Optimization and Decision-Making in the Renewable Energy Industry (pp. 109-125). (2022). *IGI Global*.
59. Seby, A., & Ravi, V. A plithogenic model for determining the best hotel chain in the Indian context. *International Journal of Hospitality and Event Management,* 2(3-4), (2022). 202-222.
*60.* Priya, R., Martin, N., & Kishore, T. E. Plithogenic cognitive analysis on instigating spiritual intelligence in smart age youth for humanity redemption. *In AIP Conference Proceedings* (Vol. 2393, No. 1). (2022, May). *AIP Publishing.*
61. Zuñiga, E. J. D., Jáuregui, G. M., Estrada, D. M. D., Masaya, N., & Tenazoa, P. STUDY OF MINERALOGY IN THE CLAY FRACTION IN REPRESENTATIVE SOILS OF PUCALLPA, PERU, BASED ON PLITHOGENIC NUMBERS.
62. Tayal, D. K., Yadav, S. K., & Arora, D. Personalized ranking of products using aspect-based sentiment analysis and Plithogenic sets. *Multimedia Tools and Applications*, 82(1), 1261-1287 (2023).
63. Wang, P., Lin, Y., Fu, M., & Wang, Z. VIKOR Method for Plithogenic Probabilistic Linguistic MAGDM and Application to Sustainable Supply Chain Financial Risk Evaluation. *International Journal of Fuzzy Systems*, 25(2), (2023). 780-793.
*64.* Sudha, S., & Martin, N. Comparative analysis of Plithogenic neutrosophic PIPRECIA over neutrosophic AHP in criteria ordering of logistics selection. *In AIP Conference Proceedings* (Vol. 2649, No. 1). (2023, June). *AIP Publishing.*

**Received:** 15 May 2023, **Revised:** 15 Aug 2023,

**Accepted:** 25 Sep 2023, **Available online:** 01 Oct 2023.

© 2023 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).