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State of Art of Plithogeny Multi Criteria Decision Making Methods

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Abstract

Plithogenic sets coined by Smarandache in the year 2018 has unveiled new research opportunities in the field of Multi criteria decision making (MCDM). The contributions and developments of new decision making approaches based on plithogeny is gaining high momentum presently. The theoretical conceptualization of different phenomenon with plithogenic sets are also applied in designing optimal solutions to the decision making problems. This review paper presents the applications of plithogenic MCDM from the year 2018 to till date in almost all the spheres of decision making scenario. The literature works of the researchers presented in this paper will certainly portray the compatibility and flexibility of plithogenic sets, operators and other decision making tools. Though the time span considered for counting on the plithogeny based works is short, the applications of plithogenic sets are growing many in number and also plithogeny based theories are amplifying in a speedy manner. This has motivated the authors to investigate on the proliferation of plithogeny applications in decision making. This review paper has focused on the dimensions of different fields to which plithogeny is applied, new plithogeny based theories, extension of plithogeny, plithogenic based operators and measures. In addition to it the data on the publications of plithogeny based articles and interests of researchers are also presented as a part of this review work. The overall impact of plithogeny in the arena of decision making science and on the researchers of the same field is well sketched in this paper with the intention and hope of inspiring plithogenic researchers.

Keywords: Plithogeny, Plithogenic MCDM, Applications

1. Introduction

Multi criteria decision making (MCDM) is a growing research area which attracts many researchers to develop new decision making techniques to accomplish the objective of finding optimal solutions. MCDM otherwise called as Multi attribute decision making (MADM) is a convoluted process entailing alternatives, criteria and feasible methods of deriving solutions. The primary aim of every decision making problem is to identify ideal alternative that highly fulfill all the criteria to a significant extent. MCDM methods are applied in different fields such as supply chain management, Education, Internet of Things, COVID-19 epidemic, Material selection for various manufacturing industries, Renewable Energy Development, Business and Banking sector, Planning, Medical, Agriculture ,construction and logistic.

Decision making under deterministic environment is not possible always as the decision making data is based on decision maker's opinions and perspectives. This happens as MCDM problems do not deal only with quantitative data but also with qualitative data. At certain instances, the decision matrix comprises of linguistic representations are handled by fuzzy MCDM methods. The theory of MCDM is integrated with fuzzy sets introduced by Zadeh [1] to handle imprecise and vague data. The fuzzy MCDM models are extended to intuitionistic fuzzy MCDM. In an intuitionistic MCDM the data representations are made using intuitionistic sets. Atanssov [2] introduced intuitionistic sets comprising membership and non-membership values. Intuitionistic MCDM methods are extended to neutrosophic MCDM to handle indeterminacy. Smarandache [3] introduced the theory of neutrosophy

to handle the condition of indeterminacy. MCDM methods discussed under the environments of fuzzy, intuitionistic and neutrosophic are more compatible in making precise decisions. But still to develop a more comprehensive genre of MCDM models Smarandache developed [4] the theory of Plithogeny. Plithogenic based MCDM are gaining more impetus at recent times as these MCDM models are more adaptive to any kind of decision making models based on the characteristics of crisp, fuzzy, intuitionistic and neutrosophic. The compatibility and comprehensive nature of plithogenic sets has motivated the authors to investigate on the plithogenic based MCDM. This review article intends to answer the following questions (i) What are the theories developed based on Plithogeny? (ii) How far the theory of plithogeny is associated with MCDM? (iii) What are the significant applications of Plithogenic MCDM? (iv)To what extent the theory of plithogeny has gained the interest of the researchers in the recent years?

The remaining contents are structured as follows: section 2 comprises the overview of the MCDM methods; section 3 elucidates on the origin and development of Plithogeny and the conceptualization of Plithogenic based theories; section 4 sketches out the applications of the Plithogeny based MCDM; section 5 presents the analysis of plithogenic publication and the last section concludes the review work with future directions

2. Overview of MCDM

The theoretical arguments of Multi criteria decision making is an integral part of Decision theory. MCDM is otherwise termed as MCDA where the latter focuses on analysis. A MCDM problem generally begins with the formulation of a primary decision making matrix with alternatives and criteria. The alternatives are referred as the options, the criteria as the characteristic features and the value of the matrix indicates the satisfactory extent of the criteria by the alternatives. The number of MCDM methods that currently exist are many in number but the process of finding optimal solution to the decision making problems follows certain steps in common.

(i) Formulation of Decision Making matrix with finite number of alternatives and criteria of the form

$$D_M(T) = \begin{pmatrix} t_{11} & t_{12} & \ldots. & \ldots. & t_{1j} \\ t_{21} & t_{22} & \ldots. & \ldots. & t_{2j} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ t_{i1} & t_{i2} & \ldots & \ldots & t_{ij} \end{pmatrix} ; \text{i=1,2…m , j=1,2…n}$$

The above matrix has m alternatives and n criteria where the values of m and n ranges from 1 to I and 1to j respectively

(ii) Computing the criterion weights Wj. At some cases the criterion weights are assumed to be equal but in some cases the criterion weights are computed using preferences and relative importance.

(iii) Normalization of the matrix

This is a very essential step in every decision making process. As the values of the decision matrix are of different ranges, the values are normalized and scaled down to the range between 0 and 1. Different methods of normalization such as linear sum, linear max-min, linear max and VIKOR are used.

(iv) Finding the weighted normalized matrix

The weighted normalized matrix is obtained by multiplying the weight vector of the criteria with the normalized matrix.

(v) Ranking of the alternatives based on the relative score values.

The alternatives are ranked after computing the score values of the alternatives. The modality of calculating the score values differs with respect to the methods. The graphical representation of any MCDM framework in general is presented in Fig.1

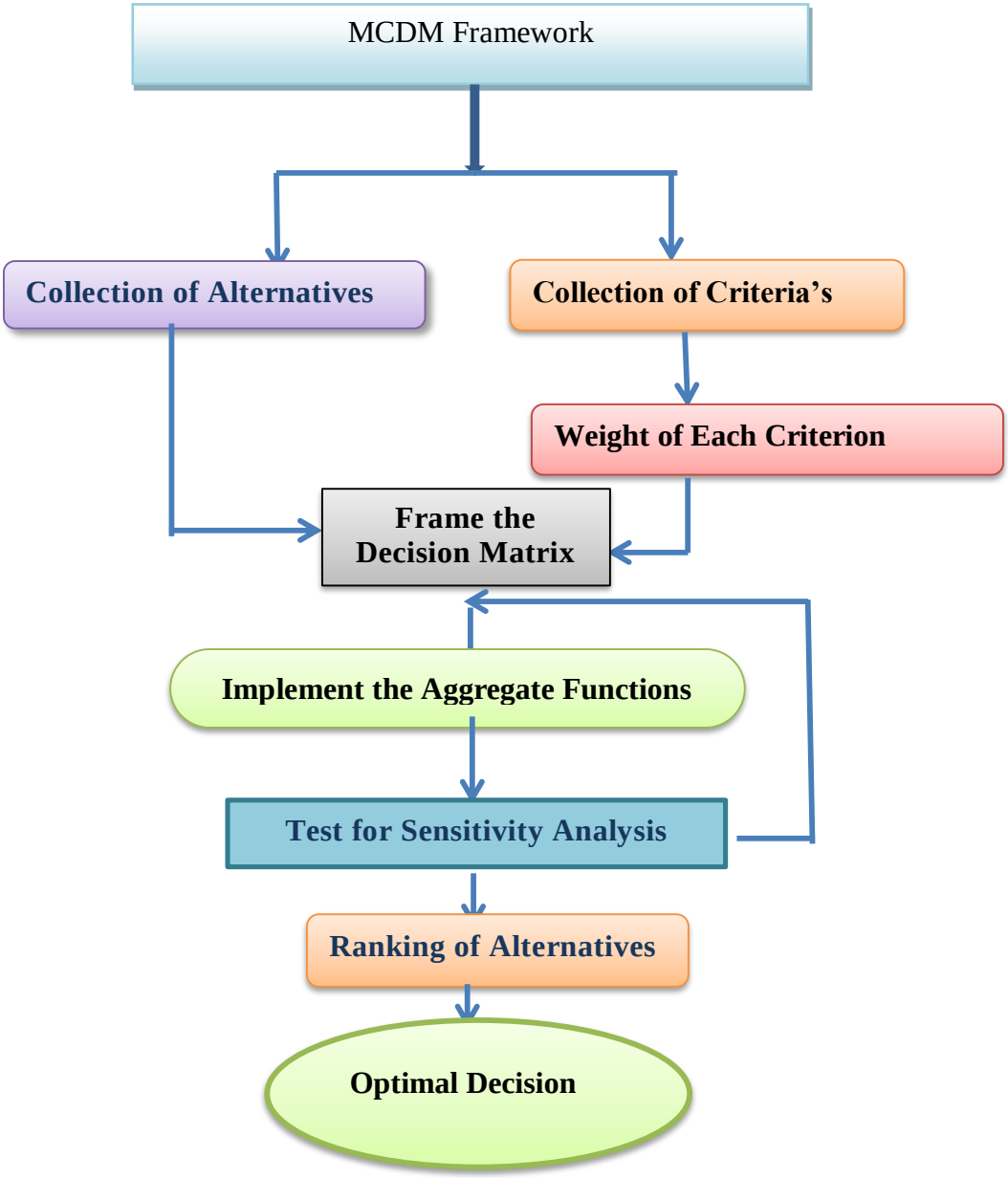

Fig.1. MCDM Framework

The MCDM methods are classified based on the following classifiers as follows

(i) Number of decision makers

(ii) Number of alternatives

(iii) Nature of the criteria

(iv) Nature of the values in the decision making matrix

(v) Goals of the decision making problem

(vi) Criterion weights computation

(vii) Calculation of the score values of the alternatives

(viii) Nature of the decision making environment

Based on the above described classifiers, many numbers of MCDM methods are developed especially to find the criterion weights and to rank the alternatives. The MCDM methods that are formulated by the researchers are presented as follows in Table 1.

Table 1 Chronological Development of MCDM Methods

S.No	MCDM Methods	Authors	Year
1	Taxonomy Method	Adanson	1763
2	Weighted Product Model (WPM)	Bridgeman	1922
3	Simple Additive Weighting (SAW)	Fish burn et al.,	1967
4	Weighted Sum Model (WSM)	L. A. Zadeh	1963
5	Multi Attribute Utility Theory (MAUT)	P.C. Fishburn, Keeney , Raiffa	1965, 1976
6	Multi-Attribute Utility Analysis (MAUA)	P.C. Fishburn	1965
7	Elimination and Choice Translating Reality (ELECTRE)	Benayoun Roy	1968
8	Multi-Attribute Utility Analysis (MAUA)	R.L. Keeney, H.R. Raiffa	1969
9	Analytic Hierarchy Process (AHP)	Thomas Saaty	1970
10	Decision-Making Trial and Evaluation Laboratory (DEMATEL)	Fonetla and Gabus	1971
11	QUALItative FLEXible (QUALIFLEX)	Paelinck , Jacquet Lagreze	1975
12	ORESTE	Roubens	1980
13	Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)	J. P. Brans , P. Vicke	1982
14	Evaluation of Mixed Data (EVAMIX)	Voogd , Martel and Matarazzo	1982
15	Grey relational analysis(GRA)	Deng	1982
16	REGIME	Hinloopen, Nijkamp, and Rietveld	1983
17	Simple Multi-Attribute Rating Technique (SMART)	Winterfeldt & Edwards	1986
18	Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)	S. Opricovic	1990

19	Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH)	Banae Costa , Vansnick	1990
20	EXPROM I & II (Extension of the PROMETHEE)	Diakoulaki , Koumoutsos	1991
21	TODIM	Gomes, Lima	1992
22	Ashby	Ashby	1992
23	Complex Proportional Assessment (COPRAS)	Zavadskas , Kaklauskas and Sarka	1994
24	The Criteria Importance Through Inter criteria Correlation (CRITIC)	Diakoulaki, Mavrotas, and Papayannakis	1995
25	Analytic Network Process (ANP)	Saaty T. T	1996
26	PAMSSEM I & II	Martel, Kiss, and Rousseau	1996
27	Multi criteria Optimization and Compromise Solution (VlseKriterijumska Optimizacija I Kompromisno Resenje) (VIKOR)	S. Opricovic	1998
28	superiority and inferiority ranking method (SIR)	Xu	2001
29	Multi-Objective Optimization by Ratio Analysis Method (MOORA)	Brauers , Zavadskas	2004, 2006
30	Case Based Reasoning (CBR)	Li, Sun, Kolodner	2008
31	Preference selection index (PSI)	Maniya , Bhatt	2010
32	Additive Ratio Assessment (ARAS)	Zavadskas ,Turskis	2010
33	Stepwise Weight Assessment Ratio Analysis (SWARA)	Kersuliene, Zavadskas, and Turskis	2010
34	Data Envelopment Analysis (DEA)	Thanassoulis, Kortelainen, and Allen	2012
35	Weighted Aggregates Sum Product Assessment (WASPAS)	Zavadskas, Turskis, Antucheviciene, and Zakarevicius in	2012
36	Kemeny Median Indicator Ranks Accordance (KEMIRA)	Krylovas, Zavadskas, Kosareva, and Dadelo	2014
37	Evaluation based on Distance from Average Solution (EDAS)	Keshavarz Ghorabaee, Zavadskas, Olfat, and Turskis	2015
38	Multi-Attributive Border Approximation area Comparison (MABAC)	Pamucar and Cirovic	2015
39	Best Worst Method (BWM)	Rezaei	2015
40	Integrated Determination of Objective CRIteria Weights (IDOCRIW)	Zavadskas and Podvezko	2016
41	PIvot Pairwise RElative Criteria Importance	Stanujkic et al.,	2017

	Assessment (PIPRECIA)		
42	Full Consistency Method (FUCOM)	Pamucar	2018
43	MultiAtributive Ideal-Real Comparative Analysis (MAIRCA)	D.S. Pamucar	2018
44	COmbined COmpromise SOlution (CoCoSo)	Morteza Y., et al	2019
45	Method based on the removal effects of criteria (MEREC)	Keshavarz-Ghorabaee et al	2021

The significant characteristics of the most commonly applied MCDM methods are measured by the nature of the method, attribute dependency and facilitation in handling qualitative and quantitative values. In general the methods are of compensatory in nature. Table 2 sketches out the core characteristics of the MCDM methods.

Table 2 Characteristics of MCDM methods

MCDM Methods	Characteristics		
	Compensatory Method	**Attributes Dependency**	**Conversion of Qualitative to Quantitative**
Weighted Sum Model (WSM)	✓	X	✓
Weighted Product Model (WPM)	✓	X	✓
Analytic Hierarchy Process (AHP)	✓	X	✓
Data Envelopment Analysis (DEA)	-	✓	✓
Analytic Network Process (ANP)	✓	✓	✓
ELimination and Choice Translating REality (ELECTRE)	✓	✓	✓
Multicriteria Optimization and Compromise Solution (VIKOR)	✓	X	✓
Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)	✓	X	✓
Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)	✓	✓	✓
Best Worst Method (BWM)	-	-	-

Case Based Reasoning (CBR)	-	-	-
Multi Attribute Utility Theory (MAUT)	✓	X	✓
DEcision-Making Trial and Evaluation Laboratory (DEMATEL)	✓	✓	✓
COPRAS	✓	X	✓
Preference selection index (PSI)	-	-	-
SMART	✓	✓	✓
REGIME	✓	X	X
ORESTE	✓	X	X
MOORA	✓	X	✓
QUALIFLEX	✓	X	X
SIR	✓	X	✓
EVAMIX	✓	X	X
ARAS	✓	X	✓
Taxonomy Method	✓	X	✓
MACBETH	✓	X	✓
WASPAS	✓	X	✓
SWARA	✓	X	-
MAIRCA	-	-	-
CRITIC	✓	✓	✓
FUCOM	-	-	-
TODIM	✓	X	✓
IDOCRIW	✓	X	✓
EDAS	✓	X	✓
PAMSSEM I & II	✓	✓	✓
EXPROM I & II	✓	✓	✓
MABAC	✓	X	✓
KEMIRA	✓	-	✓
Grey relational analysis (GRA)	-	-	-
Method based on the removal effects of	-	✓	✓

criteria (MEREC)			
COmbined COmpromise SOlution (CoCoSo)	✓	X	✓
Simple Additive Weighting (SAW)	-	X	✓

Hence the MCDM methods that are formulated by the researchers have high utility in making optimal decisions, there are few limitations. The existence of speculations about the decision making scenario in different perspectives are quite inevitable. As every decision making circumstances are inscribed with uncertainty, ambiguity and indeterminacy, it is quite natural and essential to extend the crisp decision making methods to fuzzy, intuitionistic and neutrosophic environments.

Table: 3 Pioneers of MCDM methods in Different Decision Making Environments

MCDM methods	Fuzzy MCDM	Intuitionistic MCDM	Neutrosophic MCDM	Plithogenic MCDM
AHP	Van Laarhoven and Pedrycs [5]	Jian Wu Hai-bin Huang, Qing-wei Cao [6]	Nouran M. Radwan, M. Badr Senousy [7]	Mohamed Abdel-Basset [8]
BWM	Guo Sen, Haoran Zhao [9]	Mou Qiong, Xu Zeshui, Huchang Liao[10]	Vafadarnikjoo, Amin ,Madjid, Tavana [11]	Mohamed Grida [12]
FUCOM	Galina Ilieva [13]	Arunodaya Raj Mishra, Abhishek Kumar Garg [14]	Fatih Yiğit [15]	S.Sudha & Nivetha Martin [120]
MAIRCA	Boral et al[16]	Fatih Ecer [17]	Dragan et al [18]	A.Ozcil et al[19]
TOPSIS	Chen. Or Lai et al [20]	Deepa Joshi, Sanjay Kumar[21]	A Elhassouny[22]	M. Abdel-Basset & Rehab Mohamed[23]
CRITIC	Kahraman et al [24]	Quan-Song Qi [25]	Esra Aytaç Adalı, Tayfun Öztaş [26]	Abdel-Basset et al .,[23] Korucuk, Demir, Karamasa, & Stević.,[27]
MABAC	Liang WZ, Zhao GY, Wu H, Dai B. [28]	Jia F et al,[29] Mengwei Zhao & Guiwu Wei et al [30]	Sahin R, Altun F [31]	Florentin Smarandache et al.,[32]
MACBETH	Dhouib [33]	Mustafa said Yurtyapan Erdal Aydemir [34]	Irvanizam et al.,[35]	S.Sudha & Nivetha Martin [121]
MEREC	Mohamad Shahiir Saidin et al.,[36]	Ibrahim M. Hezam et al.,[37]	-	Sudha.S , Edwin Deepak F.X , Nivetha Martin [124]

PIPRECIA	Stević et al.[123]	-	-	Alptekin Ulutas et al [123]

3. Origin and Development of Plithogeny

Smarandache is the founding father of the theory of Plithogeny. The Plithogenic sets are introduced as the generalization of crisp sets,fuzzy sets, intuitionistic sets, neutrosophic sets [38]. A plithogenic set is a quintuple of the form (P,a,V,d,c), where P is the set, a is the attribute, V is the set of attribute values, d is the degree of appurtenance and c is the degree of contradiction. The plithogenic sets are a boon to the field of decision making as it deals with attributes. These sets are very comprehensive in nature as it facilitates in accommodating multi expert's opinion and several attributes values with respective d and c values.

Smarandache [4] also developed Plithogenic based theories of probability, statistics. The notion of Plithogenic logic is also formulated as a generalization to multi valued logic [39]. Villacrés et al.,[40] applied Plithogenic logic in determining the occupational health risks. George [41] applied Plithogenic sets and logic in information analysis. Smarandache [42] has also made the extensions of neutrosophic over set/under set/off set to Plithogenic. Smarandache [43,44] has extended neutrosophic statistics to Plithogenic statistics. Smarandache and Guo [45] developed neutrosophic based plithogenic optimization. The plithogenic statistics is considered to be the most generalized form of the statistics. Castro Sánchez et al., [46] have applied the neutrosophic and plithogenic statistical concepts in making decisions on developing educational field. Prem Kumar Singh [47] has applied Plithogenic sets in multivariate data analysis.

Smarandache [48,49] was the pioneer of Hypersoft sets and Plithogenic Hypersoft sets which are the extensions of soft sets. Shawkat et al.,[50] introduced Plithogenic soft sets. Smarandache [51] has also introduced new types of soft sets such as indeterm soft set, indeterm Hypersoft set, Tree soft sets. Rana et al.,[52] introduced plithogenic whole hypersoft set and generalized plithogenic whole hypersoft set. Dhivya and Arockia Lancy [53,54] have developed Near plithogenic hypersoft sets and discussed the properties of the sets. Nivetha Martin and Smarandache [55,56] have introduced combined plithogenic hypersoft sets and extended plithogenic Hypersoft sets with dual dominant attributes. Shazia Rana et al., [57] together designed Plithogenic Subjective Hyper-Super-Soft Matrices with different levels of ranking

Vasantha and Smarandache [58] developed Plithogenic graphs. Sultana et al., [59] applied plithogenic graphs in analysing the spread of corona virus. Bharathi [60] introduced plithogenic product fuzzy graphs and studied its applications in social networks. Prem kumar singh [61-63] has discoursed on single valued plithogenic graph, single valued neutrosophic plithogenic graph and Intuitionistic plithogenic graph. Smarandache [64] has also developed the notion of n-Super Hyper Graph and Plithogenic n-Super Hyper Graph. Smarandache and Nivetha Martin [65] have developed concentric plithogenic hypergraph based on Plithogenic Hypersoft sets.

Researchers have also explored plithogenic based algebraic structures. Smarandache [66-68] laid the foundation of Plithogenic algebraic structures. Gayen et al., [69] plithogenic Hypersoft subgroups. Basumatary et al., [70] investigated the topological properties based on *plithogenic neutrosophic Hypersoft*. Taffach, & Hatip [71] presented a brief review of Symbolic 2-Plithogenic Algebraic Structures. Taffach et al.,[72] discoursed on Plithogenic rings. Taffach & Nader Mahmoud [73] discussed on the fusion of Symbolic Plithogenic Sets and Vector Spaces. Priyadharshini & Nirmala Irudayam[74] have explored plithogenic based topological spaces and their properties. Merkepci & Abobala [75] evolved the theory of Symbolic 2-Plithogenic Rings. Al-Basheer et al., [76] elicited on Symbolic 3-Plithogenic Rings and their Algebraic Properties. Smarandache [66] presented an overall view of the plithogenic algebraic structures and symbolic plithogenic algebraic structures. Taffach et

al.,[77] have explored Plithogenic Number Theory and algebraic equations. Khaldi.,[78] formulated algorithms for solving algebraic equations with Symbolic 2-Plithogenic numbers.

Plithogenic numbers is also investigated by several researchers. Nivetha et al.,[79] have introduced Plithogenic numbers. Followed by Noel Batista Hernández et al.,[80] have applied plithogenic numbers in assessing competency of the students. Raúl Comas Rodríguez et al.,[81] have applied in evaluation of education and society. Zuñiga et al.,[82] have used plithogenic numbers in study of the soil attributes

Nivetha Martin et al.,[79]introduced Plithogenic Sociogram. Sudha, Nivetha Martin , Florentin Smarandache [83] introduced extended plithogenic sets and applied the same in plithogenic sociogram. The plithogenic sociogram approaches are the extensions of neutrosophic sociogram approaches. These are used as alternatives of MCDM methods. Nivetha Martin and Florentine Smarandache [84] have introduced the theory of Plithogenic Cognitive Maps to make optimal decisions. Sujatha et al.,[85] have applied Plithogenic Cognitive Maps in making analysis of the novel corona virus. Nivetha Martin et al.,[86] have developed the concept of new plithogenic sub cognitive maps with mediating effects. Priya and Nivetha Martin [87] introduced Induced Plithogenic Cognitive Maps with Combined Connection Matrix. Priya, Martin, & Kishore [88] have applied PCM in the field of behaviour modification.

Priyadharshini et al.,[89] have developed plithogenic cubic sets and have explored their properties with suitable illustrations. Prem kumar Singh [90] has introduced complex plithogenic set. The Plithogenic sets are applied to other physical fields. Smarandache [91] has coined Physical plithogenic sets. Within a very short span of time of the conceptualization of Plithogeny, the plithogenic sets are widely applied in almost all the domains of mathematics.

4. Applications of Plithogeny based MCDM

This section presents the applications of Plithogenic sets in the arena of decision making. The plithogenic representations, plithogenic operators are integrated with decision making elements to make optimal decisions. The plithogenic concepts that are presented in the section [3] are applied in making decisions based on multi attributes. The plithogenic based decision making are used in solving ranking based problem. It is also used in making assessments and evaluation study. The plithogenic environment is extensively applied in solving various problems. Abdel-Basset et al.,[8] in green supply chain management, Abdel-Basset et al.,[92] in making evaluations of hospital administration, Tayal et al., [93] in ranking of products, Rously et al., [94] in prioritizing. Gómez et al.,[95] in evaluating strategies of promoting education, Fernández et al.,[96] in selecting investment projects, Moncayo et al.,[97] in defining strategies, Öztaş et al.,[98] in performance evaluation, Pai, & Prabhu Gaonkar [99] in making risk assessments on evidential reasoning. Rehab Mohamed et al.,[12] in evaluating the performances of IoT based supply chain. M. Abdel-Basset et al.,[32] in supplier selection. Abdel-Basset et al.,[100] in financial performances. In the above mentioned plithogenic based decision making models, the plithogenic representations are used to represent data.

Some of the MCDM methods presented in Table 4, are also discussed under plithogeny. The applications of the extended plithogenic based MCDM methods are described as follows. Ansari and Kant [101] have applied plithogenic based neutrosophic Analytical Hierarchy Process in handling a decision-making problem on supply chain. TOPSIS is one of the most preferred MCDM method. Sankar et al.,[102] applied Plithogenic TOPSIS in modelling COVID- 19 problem. Mohamed Abdel-Basset & Rehab [23] used TOPSIS-CRITIC in supply chain management. Nivetha Martin [103] employed TOPSIS-SWARA in food processing technology. Abdullah Ozcil et al. [19] used plithogenic MAIRCA in building novel decision making model. Sudha & Nivetha Martin [104] developed TOPSIS integrated Plithogenic Cognitive Maps in making optimal decisions on the problems based on the evaluation of teachers performance. Korucuk et al.,[27] formulated plithogenic CRITIC decision model to optimize logistics based problems. Sudha & Nivetha Martin [105] applied

the integrated Plithogenic CRITIC-MAIRCA in making decisions on feasible livestock feeding stuffs. Wang et al., [106] devised multi attribute group decision making using Plithogenic VIKOR with linguistic representations. Wang et al.,[107] used rough numbers in framing plithogenic neutrosophic based decision making model. Ulutaş & Topal [108] used Plithogenic PIPRECIA in dealing logistics problem. Abdel-Basset et al.,[109] designed plithogenic best-worst method in making decisions on supply chain. Sudha & Nivetha Martin [110] made comparative analysis of the efficiency of plithogenic and neutrosophic best and worst method.

Shio Gai Quek et al.,[111] used Plithogenic entropy measures in solving a multi-attribute decision making. Gomathy et al.,[112] applied plithogenic sets in making decisions on health dynamics. Abdel-Basset et al., [8] used quality functions in devising hybrid decision making models in solving supply chain management problems. Priyadharshini and Nirmala Irudayam [113] used refined and single valued plithogenic neutrosophic sets in solving MCDM problems. Nivetha Martin et al [114]., used PROMTHEE Plithogenic Pythagorean Hypergraphic Approach in Smart Materials Selection. Walid Abdelfattah [115] developed plithogenic DEA in assessment based problems.

Inaddition to the applications of the Plithogenic based MCDM methods in making optimal decisions. Florentin Smarandache and Nivetha Martin[116] have used Plithogenic n- Super Hypergraph in making Novel Multi -Attribute Decision Making. Muhammad Rayees Ahmad et al., [117] used Plithogenic Hypersoft Sets with Fuzzy Neutrosophic representations in framing novel decision making model. Dhivya & Arokia Lancy [118] constructed a multi attribute decision-making model with Heronian Mean Aggregation Operators using the representations of near plithogenic neutrosophic hypersoft representations. Sudha and Nivetha Martin [119] applied combined Plithogenic Hypersoft sets in making optimal decisions on business analytics tools. The Table 4 presents the applications of the above discussed Plithogenic based MCDM methods.

Table:4 Applications of the Plithogenic MCDM methods

Plithogenic MCDM Methods	**Problem Specification**
Plithogenic TOPSIS	• Quality Function Deployment for Selecting Supply Chain Sustainability Metrics • COVID-19 pandemic problem
Plithogenic VIKOR	Hospital medical care systems
Plithogenic AHP	Eco-innovation practices in supply chain
Plithogenic TOPSIS-CRITIC	Risk management in sustainable supply chain
Plithogenic MAIRCA	Constructing innovative decision making model
Plithogenic BWM & VIKOR	Evaluating the Performance of IoT Based Supply Chain
Plithogenic AHP,TOPSIS & VIKOR	Financial performance evaluation of manufacturing industries.
Plithogenic MABAC, BWM	Supplier Selection problem
Plithogenic SWARA-TOPSIS	Food Processing Methods with Different Normalization Techniques
PROMTHEE Plithogenic Pythagorean Hypergraph	Smart Materials Selection

Plithogenic Best-Worst method	Supply chain ,Evaluation of Teaching & Learning process
Plithogenic CRITIC-MAIRCA	Feasible Livestock Feeding Stuffs
TOPSIS-Plithogenic Cognitive Maps	Performance of teachers being evaluated
Plithogenic CRITIC	Optimize logistics problems
Plithogenic VIKOR	Group decision making problem
Plithogenic PIPRECIA	Logistics Selection problem
Plithogenic FUCOM-MAIRCA	sustainable factors and suppliers for transforming business sectors to Green Globe Creators

Analysis on Publications

This section presents the analysis of the publications of the articles based on Plithogenic MCDM. The list of journals in which the article are published are presented in Table 5.

Table : 5 List of the Journals

Name of the Journal	**Number**
Neutrosophic Sets and Systems (NSS).	27
Infinite Study	4
International Journal of Neutrosophic Science (IJNS)	17
AIP Conference Proceedings	1
MDPI- Symmetry	3
Intelligent and Fuzzy Techniques- Smart and Innovative Solutions	2
In Cognitive Intelligence with Neutrosophic Statistics in Bioinformatics. Academic Press	1
International Journal of Sustainable Engineering	1
Acta Scientific Computer Sciences	1
Multimedia Tools and Applications	1
Artificial intelligence in medicine	2
Octogon Mathematical Magazine	1
International Journal of Creative Research Thoughts (IJCRT)	1
International Journal of Mechanical Engineering	1
Indian Journal of Natural Sciences (IJONS)	1
Journal of Intelligent & Fuzzy Systems,	1
Journal of Fuzzy Extension and Applications	3
AIP Publishing LLC	3
Advances in Decision Making	1
Journal of Cleaner Production	1
International Conference on Intelligent and fuzzy systems	1
Mathematics-MDPI	1
Computers, Materials & Continua., Tech Press Science.	1
Risk Management	1
Artificial intelligence in medicine.	1
International Journal of Fuzzy Systems	1
Sustainability	1
IGI Global - Optimization and Decision-Making in the Renewable Energy	1

Industry(Book)	
Stochastic Modeling & Applications	1
Journal of Ambient Intell Humaniz Comput	1
Indian Journal of Science and Technology	1
Optimization Theory Based on Neutrosophic and Plithogenic Sets	1
Research gate	1
International Journal of Fuzzy Logic and Intelligent Systems	1
IJSRM- International Journal of Scientific Research and Management	1
Galoitica Journal Of Mathematical Structures And Applications (GJMSA)	2
REVISTA INVESTIGACION OPERACIONAL	1
Current Advances in Mechanical Engineering	1
International Research Journal of Modernization in Engineering Technology and Science	1

5. Conclusion and Future Directions

This review paper has presented an extensive overview of the philosophy of plithogeny and its applications in decision making. The ongoing research works in the plithogenic field is an actual substantiation for the effectiveness of plithogenic principles in making optimal decisions. The theoretical developments of plithogeny constructed by Smarandache are articulated by the plithogenic researchers in terms of excellent applications. The applications of plithogeny have smoothened the hurdles of determining solutions to the problems of varied kinds. The manifestations of plithogeny embedded with realistic applications in various fields are also bountiful. The recent developments and extensions of plithogenic sets are the instances of the comprehensives of plithogenic sets. As the researches and contributions of plithogenic sets are persisting with vibrancies, the opportunities of integrating plithogeny with other facets of decision making models are in manifold. The construction of new kinds of sets at recent times shall also be dealt with plithogeny. The contributions of Plithogenic sets are scaled up within a very short span of time and certainly, it is expected to reach a huge number in the coming decades.

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