COMBINED PLITHOGENIC HYPERSOFT SETS IN DECISION MAKING ON SUPPLIER SELECTION WITH DIFFERENT MCDM APPROACHES

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Abstract:

Decision making methods integrated with Plithogenic sets are highly feasible and resilient in designing optimal solutions. This research work identifies the research gaps of limited applications of combined plithogenic hypersoft sets (CPHSS) and hence proposes a supplier selection decision problem with an integrated approach combining CPHSS with MCDM methods. A generalized form of Plithogenic accuracy function is used in determining the plithogenic accuracy matrix to which the prominent ranking methods of TOPSIS, ELECTRE, VIKOR and MAIRCA are applied. The proposed hybrid decision approach is illustrated using supplier selection decision problem as a case study. The ranking results are compared with normal and combined plithogenic hypersoft sets. The sensitivity analysis performed exhibits the efficacy of combined plithogenic hypersoft sets in representing the realistic data. This integrated decision framework contributes to Plithogenic applications of handling complex decision systems.

1 Introduction

Smarandache [1] developed the philosophy of Plithogeny and constructed plithogenic sets as the generalization of crisp, fuzzy and intuitionistic sets. The plithogenic sets are represented as a quintuple of the form (P, a, V, d, c) with set P, dominant attribute a, set of attribute values V, degree of appurtenance d and degree of contradiction c. Plithogenic sets are characterized based on attributes and attribute values which facilitate to resolve intricate decisioning process. Martin et al [2] conceptualized plithogenic sociogram and plithogenic numbers to handle social dynamics. Hurtado et al [3] applied plithogenic based statistical measures to address digital security issues. Martin et al [4] demonstrated the efficacy of plithogenic sets in diagnosis of Covid-19 using plithogenic sub-cognitive maps with mediating effects. Researchers also developed Plithogenic structures. Basumatary et al [5] discoursed some properties of plithogenic neutrosophic hypersoft almost topological group. Gayen et al [6] discoursed on plithogenic hypersoft subgroup. Dhivya and Lancy [7,8] also contributed to the expansions of near plithogenic hypersoft sets and its properties.The developments and applications of plithogenic sets to diverse decision making circumstances exhibit the potency of such a generalized set.

The notion of plithogeny is integrated with various representations of sets that are applied widely in dealing attributes and one such kinds of sets are hypersoft sets. Smarandache[9] extended soft sets to hypersoft sets, indeterm hypersoft sets. Abbas et al [10] and Debnath et al [11] contributed to the theoretical developments of fuzzy hypersoft set. Plithogenic hypersoft sets are introduced by Smarandache[12] as a

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generalization of hypersofts sets of the forms of fuzzy, intuitionistic and neutrosophic.The hypersoft set representations facilitate in considering different attributes into study with single degree of appurtenance. However, in Plithogenic hypersoft sets the degree of appurtenance pertains to each of the attribute values subjected to each of the attributes. Plithogenic hypersoft sets are more comprehensive in nature and applied in different decision-making problems. Rana et al [13] employed Plithogenic fuzzy whole hypersoft set to make optimal decisions on the alternatives based on different attributes. Martin and Smarandache[14] developed the notion of concentric plithogenic hypergraphs. Ahmad and Afzal [15] associated plithogenic hypersoft sets with AI to develop COVID 19 decision model. Martin et al [16]formulated a disease decision model based on extended plithogenic hypersoft sets with dual dominant attributes. Majid et al [17] formulated a decision model on dam site selection using a Plithogenic Multipolar Fuzzy Hypersoft Set. Hema et al [18] framed a decision model with interval-valued plithogenic hypersoft sets. Plithogenic based hypersoft sets are more efficient in handling decision problems with multi-attributes with linear dependency and relational complexity.

Researchers have integrated plithogenic hypersoft sets with multi-criteria decison methods to develop hybrid decioning models.Muhamad et al[19] outlined a decision model with MCDM integrated Plithogenic hypersoft approach especially the method of TOPSIS using plithogenic accuracy function for neutrosophic representations. Sudha et al [20] attempted the same with MAIRCA method. In these plithogenic representations the degree of prudence assumes either of the values of fuzzy, intuitionistic or neutrosophic. However, in a realistic circumstance, the degree of apprutenance may assume a combination of values and this motivated Martin and Smarandache [21] to develop the concept of combined plithogenic hypersoft sets in which the degree of appurtenance assumes a combination of either crisp, fuzzy, intuitionistic or neutrosophic. The plithogenic hypersoft set representations assumes any one of the above representations for the degree of appurtenance but in the case of combined, a varied combinations are used to facilitate the decision makers to express their view on the relation between the alternatives and the attributes. At certain instances, the decision makers may be aware of the degree of appurtenance between the alternatives and the attribute values and in few cases the appurtenance degree may be in fuzzy, intuitionistic and neutrosophic based on their perception and intuitions. The integration of MCDM methods with combined plithogenic hypersoft sets has not been explored to the best of our knowledge and this serves as the motivation of this research work. Also, plithogenic accuracy function in its general form is employed in the hybrid approach to ease the intergation of MCDM methods and to find optimal solutions.The remaining contents of this work is presented in the following sections. A brief literature review on the application of MCDM methods applied in supplier selection is presented in section 2. The basic definitions are outlined in section 3. The methodology is presented in section 4. The proposed model is applied to supplier selection problem in section 5. The results obtained using the proposed model is compared with the results obtained using neutrosophic representations in section 6. The last section summarizes the work with future directions.

2 Related Works

This segment presents the applications of the most applied multi-criteria decision-making methods in supplier selection (SS). The recent works in this domain of application considered for drawing inferences are tabulated in Table 1. This section also identifies the research gaps and presents the significant contributions of this work.

Table 1. State of Art of MCDM in Supplier Selection

Author & Year	MCDM Method Applied in Supplier Selection	Nature of the Decisioning Problem
Nivetha Martin &Sudha (2024) [20]	Plithogenic Hypersoft and MAIRCA	Supplier selection
Shafi Salimi and Edalatpanah (2020) [22]	Fuzzy AHP and D numbers	Supplier selection
Ecer (2021) [23]	FUCOM and MAIRCA	Sustainable supplier selection
Yiğit (2023) [24]	ELECTRE	Supplier selection in the food and beverage industry
Asadabadi et al. (2023) [25]	Stratified BWM-TOPSIS	Supplier selection for environmental sustainability

Author & Year	MCDM Method Applied in Supplier Selection	Nature of the Decisioning Problem
Sharma & Tripathy (2023) [26]	Fuzzy TOPSIS and QFD	Supplier evaluation and selection
Nurprihatin et al. (2023) [27]	AHP and TOPSIS	Supplier selection in the construction industry
Alkolid et al. (2023) [28]	BWM and VIKOR	Green supplier selection in the Indonesian manufacturing sector
Zhang et al. (2023) [29]	Regret theory and VIKOR	Supplier selection under disruption risk
Hosseini Dolatabad et al. (2023) [30]	Fuzzy cognitive map and hesitant fuzzy linguistic VIKOR	Supplier selection in the Industry 4.0 era
Yiğit, S. (2023) [31]	ELECTRE	Supplier selection in the food and beverage industry
De Oliveira et al. (2023) [32]	Hesitant fuzzy VIKOR	Supplier selection
Rahardjo et al. (2023) [33]	DANP and VIKOR	Sustainable supplier selection in the electronics industry
Luo et al. (2023) [34]	VIKOR with single-valued neutrosophic sets	Sustainable supplier selection
Wang et al. (2023) [35]	Enhanced TODIM and VIKOR	Green supplier selection
Hajiaghaei-Keshteli et al. (2023) [36]	Pythagorean fuzzy TOPSIS	Green supplier selection in the food industry
Khan & Khan (2023) [37]	Fuzzy DEMATEL and Fuzzy TOPSIS	Supplier selection and ranking
Dhumras et al (2023) [38]	TOPSIS with R-norm q-rung picture fuzzy information measure	Green supplier selection
Wang et al (2023) [39]	Complex intuitionistic fuzzy DOMBI prioritized aggregation operators	Resilent green supplier selection
Nafei et al. (2024) [40]	Smart TOPSIS with neural network	Green supplier selection in sustainable manufacturing
Phan Ha et al. (2024) [41]	AHP and TOPSIS	Sustainable supplier selection in the apparel industry
Masudin et al. (2024) [42]	ANP and TOPSIS	Sustainable raw material supplier selection
Zhao et al. (2024) [43]	AIOWA-CRITIC and CPT-TOPSIS	Green supplier selection in China
Sun et al. (2024) [44]	Extended TOPSIS and BWM	Resilient supplier selection
Alora & Gupta (2024) [45]	BWM and VIKOR	Supplier selection based on MSME partner finance capability
Zhu & Wang (2024) [46]	BWM and VIKOR	Green supplier selection under multi-granularity linguistic environment
Khorram et al. (2024) [47]	DEMATEL, QFD, TOPSIS, and VIKOR	Fuzzy multi-criteria supplier selection problem
Varchandi et al. (2024) [48]	Best-Worst Method and Fuzzy TOPSIS	Resilient-sustainable supplier selection
Puspitasari & Febriani (2024) [49]	AHP-TOPSIS	Material supplier selection
Yalçın (2024) [50]	IVPF-AHP and VIKOR	Supplier selection of 3D printers

Author & Year	MCDM Method Applied in Supplier Selection	Nature of the Decisioning Problem
Ozensel & Efe (2024) [51]	MAIRCA with fuzzy number	Smart supplier selection
Suzana et al. (2024) [52]	Fuzzy AHP and ELECTRE	Supplier selection process in Indonesia
Hesami (2024) [53]	Hybrid ANP-TOPSIS	Strategic supplier selection in reverse logistics under rough uncertainty
Ambilkar et al (2024) [54]	Neutrosophic best–worst	Supplier selection in additively manufactured trinkets
Mohamed et al (2024) [55]	Vague Theory	Optimal blockchain supplier selection
Jana et al (2024) [56]	MABAC with biploar fuzzy	Supplier selection

From the related works presented above, it is observed that the methods of TOPSIS, VIKOR, ELECTRE and other few MCDM methods are applied in supplier selection of different industries with varied focus. From the literature, the following shortcomings are also identified.

(i) Applications of Combined plithogenic hypersoft sets are very limited.
(ii) Combined Plithogenic hypersoft sets are not integrated with any of the MCDM approaches
(iii) Supplier selection-based decision problem is not addressed with such an integrated or hybrid model.

To overcome these research gaps, this research work attempts in evolving a decision-making model by integrating combined plithogenic hypersoft sets with MCDM approach considering generalized plithogenic accuracy function.

3 Preliminaries

This section presents few definitions pertinent to our work. The basic definitions of Plithogenic sets are presented from the works of Smarandache. The plithogenic accuracy is also defined in generalized form.

3.1 Plithogenic set [1]

A plithogenic set is a quintuple of the form (P,a,V,d,c) with P the set, $P \subseteq \mathcal{U}^*$, the universal set, 'a' is the attribute, V is the set of attribute values, d the degree of appurtenance and c the degree of contradiction. The plithogenic sets is purely attribute based.

3.2 Plithogenic Hypersoft sets [12]

Let $X \subset U$ and $C = A_1 \times A_2 \times \dots \dots A_{n,}$ where $n \geq 1$ and A_i is the set of all attribute values of the attribute $a_{i,}$ $i = 1,2,3,\dots\dots n$. Each attribute value γ possesses a corresponding appurtenance degree $d(x,\gamma)$ of the member $x \in X$, in accordance with some given condition or criteria. The attribute value of degree of appurtenance is a function that is defined by (1):

$$d: X \times C \rightarrow P\left([0,1]^j\right), \quad \forall x \in X, \tag{1}$$

Furthermore, the degree of contradiction between any two attribute values of the same attribute is a function given by (2):

$$c: A_i \times A_i \rightarrow P\left([0,1]^j\right), \quad 1 \leq i \leq n, \; j = 1,2,3. \tag{2}$$

3.3 Combined Plithogenic Hypersoft sets [21]

Let $X \subset U$ and $C = A_1 \times A_2 \times \dots \dots A_{n,}$ where $n \geq 1$ and A_i is the set of all attribute values of the attribute $a_{i,}$ $i = 1,2,3,\dots\dots n$. Each attribute value γ possesses a corresponding appurtenance degree $d(x,\gamma)$ of the member $x \in X$, in accordance with some given condition or criteria. The attribute value of degree of appurtenance is a function that is defined by either (3):

$$d: X \times C \rightarrow P([0,1]), d: X \times C \rightarrow P([0,1]^2), d: X \times C \rightarrow P([0,1]^3), \quad \forall x \in X \tag{3}$$

3.4 Generalized Plithogenic Accuracy Function

Let $d(a_{ij}, F_g)$ represents the degree of association between the attribute values and the alternatives, $d(a_{ik}, F_g)$ is with respect to the dominant attribute values and $c(a_{ij}, a_{ik})$ is the degree of contradictions. Then the Plithogenic accuracy function is defined as (4):

$$d(a_{ij}, F_g) + d(a_{ik}, F_g) * c(a_{ij}, a_{ik}) \tag{4}$$

Let $d(a_{ij}, F_g) = b$ and $d(a_{ik}, F_g) = e$, $c(a_{ij}, a_{ik}) = c$. In case of crisp, it is b + e*c where b, e $\in \{0,1\}$. In case of Fuzzy, b, e $\in [0,1]$, In case of intuitionistic, b, e $\in [0,1]^2$ i.e $\frac{b_1+b_2}{2} + \frac{e_1+e_2}{2} * c$, and in case of neutrosophic, b, e $\in [0,1]^3$ i.e $\frac{b_1+b_2+b_3}{3} + \frac{e_1+e_2+b_3}{3} * c$.

4 Methodology of the Proposed Decision Approach

This section presents the steps involved in the proposed method obtained by integrating both combined plithogenic hypersoft sets with MCDM methods. This decision approach is a two phased process. The first phase involves the construction of plithogenic accuracy matrix based on combined plithogenic degrees of appurtenance with generalized plithogenic accuracy function. The second phase involves the utility of several multi- criterion decision methods to rank the alternatives. The schematic representation of the steps involved in each of the two phases are presented as follows in Figs. 1 and 2 respectively.

Phase I: Formulation of Decision-Making Matrix

Step 1: Problem Definition

The decisioning problem of supplier selection is defined initially by selecting the alternatives, attributes or criteria and attribute values. Let S1, S2 ...Sn be the alternatives, A1, A2… Am be the attributes with attribute values of the form A11, A12... A1i, A21, A22, A2j… Am1, Am2... Amp.

Step 2: Tablulation of Appurtenance degrees based on CPHSS

The appurtenance degrees of the alternatives with the attribute values are tabulated using the the representations of CPHSS (Table 2).

Table 2. Tabulated appurtenance degrees of the alternatives

Alternatives	A11		......	A21	......	....	Am1	....	Amp
S1	d(S1, A11)		......	d(S1, A21)	......	......	d(S1, Am1)	......	d(S1, Amp)
S2	d(S2, A11)		......	d(S2, A21)	......	......	d(S2, Am1)	......	d(S2, Amp)
:									
:									
Sn	d(Sn, A11)		......	d(Sn, A21)	......	......	d(Sn, Am1)	......	d(Sn, Amp)

Step 3: Determination of Dominant Attribute Value

To each of the attribute Ak chosen for decisioning, the dominant attribute values Agh are decided based on the nature of decisioning problem.

Step 4: Computation of the Contradiction Degrees

The contradiction degrees of the attribute values (Ak, Agh) with that of the dominant attribute values are computed.

Step 5: Construction of Decision-making matrix

The decision making matrix is constructed using generalized plithogenic accuracy function of the form $d(a_{ij}, F_g) + d(a_{ik}, F_g) * c(a_{ij}, a_{ik})$ as mentioned in Definition 3.4.

The above-described steps are graphically presented in Fig. 1 for better understanding.

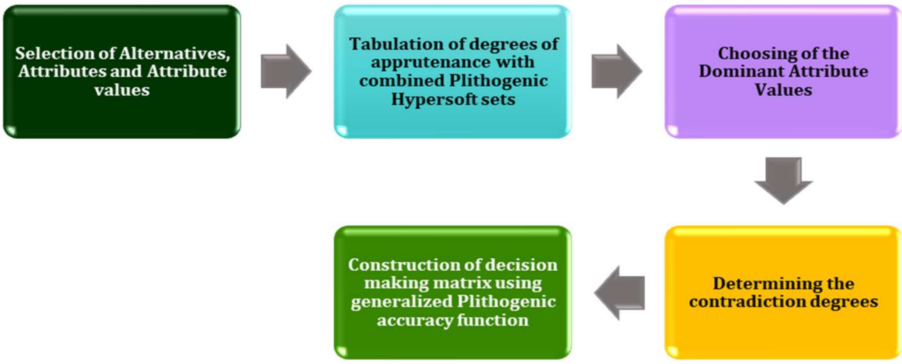

Figure 1. Steps Involved in Phase I

Phase II: Ranking of the Alternatives

In this phase the multi-criterion decision making methods are applied to rank the alternatives. The general procedure followed in MCDM methods are presented in Fig. 2 as follows.

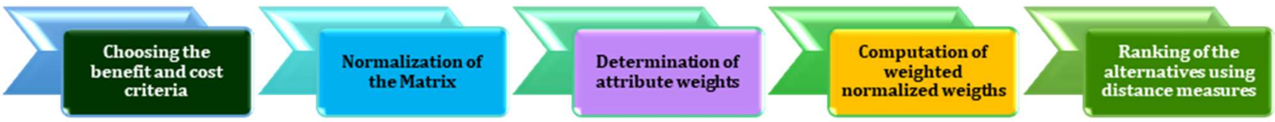

Figure 2. Steps Involved in Phase II

However, in this research work, the most applied MCDM methods of TOPSIS, ELECTRE, VIKOR and MAIRCA are considered and the steps of each of the methods are outlined in Table 3.

Table 3. Step wise MCDM Procedure

TOPSIS	ELECTRE	VIKOR	MAIRCA
Technique for Order Preference by Similarity to Ideal Solution	ELimination Et Choix Traduisant la REalité	VIseKriterijumska Optimizacija Kompromisno Resenje	Multi-Attribute Ideal-Real Comparative Analysis
General Steps Involved in the methods			
Construction of the intial decision matrix $X = [x_{ij}]_{m\times n}$ with alternatives Ai and criteria Cj.	Construction of the intial decision matrix $X = [x_{ij}]_{m\times n}$ with alternatives Ai and criteria Cj.	Construction of the intial decision matrix $X = [x_{ij}]_{m\times n}$ with alternatives Ai and criteria Cj.	Construction of the intial decision matrix $X = [x_{ij}]_{m\times n}$ with alternatives Ai and criteria Cj.

TOPSIS	ELECTRE	VIKOR	MAIRCA
Technique for Order Preference by Similarity to Ideal Solution	ELimination Et Choix Traduisant la REalité	VIseKriterijumska Optimizacija Kompromisno Resenje	Multi-Attribute Ideal-Real Comparative Analysis
Classification of the critera into benefit (B) and cost (C) categories.	Classification of the critera into benefit (B) and cost (C) categories	Classification of the critera into benefit (B) and cost (C) categories	Classification of the critera into benefit (B) and cost (C) categories
Normalization of the Matrix: $r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m}(x_{ij})^2}}$	$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m}(x_{ij})}$	$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m}(x_{ij})^2}}$	$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m}(x_{ij})}$
Weighted Normalized Matrix: $v_{ij} = w_j r_{ij}$	Weighted Normalized Matrix: $v_{ij} = w_j r_{ij}$	Weighted Normalized Matrix: $v_{ij} = w_j r_{ij}$	Weighted Normalized Matrix: $v_{ij} = w_j r_{ij}$
Specific Steps Involved in the methods			
Finding the Positive (v_j^+) and Negative (v_j^-)Ideal Solutions: $v_j^+ = \max(v_{ij} \mid j \in B)$ $\min(v_{ij} \mid j \in C)$ $v_j^- = \min(v_{ij} \mid j \in B)$ $\max(v_{ij} \mid j \in C)$	Construction of Concordance and Discordance sets Concordance: $c_{kl} = \sum_{j \in p_{kl}} w_{j,} P_{kl} = \{j \mid v_{kj} \geq v_{ij}\}$ Discordance: $D_{kl} = \max_{j \in Q_{kl}} \lvert v_{kj} - v_{lj} \rvert, Q_{kl} = \{j \mid v_{kj} < v_{lj}\}$	Calcualtion of Utility Measure $S_i = \sum_{j=1}^{n} w_j \cdot \frac{f_j^* - x_{ij}}{f_j^* - f_j^-},$	Calculate the Preferences of alternatives $P(A_i) = \frac{1}{r}, \sum_{i=1}^{r} P(A_i) = 1$ Calculate the Expected theoretical matrix $T_P = P(A_i) * \omega_j$
Calculation of Distance between Positive and Negative Ideal solutions $S_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2}$ $S_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}$	Formulation of Concordance and Discordance matrices Concordance Matrix $C_{kl}^{D} = \begin{cases} 1 \text{ if } C_{kl} \geq c \\ 0 \text{ otherwise} \end{cases}$ Discordance Matrix $D_{kl}^{D} = \begin{cases} 1 \text{ if } D_{kl} \leq d \\ 0 \text{ otherwise} \end{cases}$	Calculation of Regret Measure $R_i = \max_j [w_j \cdot \frac{f_j^* - x_{ij}}{f_j^* - f_j^-}]$	Determine the Actual matrix $T_R \begin{pmatrix} t_{r11} & t_{r12} & \ldots. & \ldots. & t_{r1s} \\ t_{r21} & t_{r22} & \ldots. & \ldots. & t_{r2s} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ t_{rs1} & t_{rs2} & \ldots & \ldots & t_{rrs} \end{pmatrix}$ For benefit criteria, take maximum value of preference and non-benefit cost type, choose minimum value of preference $T_{Rij} = T_{Pij} * \left(\frac{x_{ij} - \min x_i}{\max(x_i) - \min x_i}\right)$; $T_{Rij} = T_{Pij} * \left(\frac{x_{ij} - \max x_i}{\min(x_i) - \max x_i}\right)$
Calculation of Relative Closeness Measures.	Threshold and dominance analysis	Computing of the index Qi	Construction of Total Gap matrix T_G $T_G = T_P - T_R$; where $G = g_{ij} \in 0, T_{Pij} - T_{Rij}$ & $T_{Pij} > T_{Rij}$

TOPSIS	ELECTRE	VIKOR	MAIRCA
Technique for Order Preference by Similarity to Ideal Solution	ELimination Et Choix Traduisant la REalité	VIseKriterijumska Optimizacija Kompromisno Resenje	Multi-Attribute Ideal-Real Comparative Analysis
$C_i = \frac{S_i^-}{S_i^+ + S_i^-}$		$Q_i = v.\frac{S_i - S^*}{S^- - S^*} + (1 - v).\frac{R_i - R^*}{R^- - R^*}.$	
Ranking of the alternatives based on the score values. Alternatives with high score values are given more prioroties and preferences.	Ranking of the alternatives based on the score values. Alternatives with high score values are given more prioroties and preferences.	Ranking of the alternatives based on the score values. Alternatives with high score values are given more prioroties and preferences.	Ranking the Alternatives $Q_i = \sum_{j=1}^{n} g_{ij}$; i= 1, 2…...m. Alternatives with low score values are given more prioroties and preferences.

By following the above steps described in the above table, the optimal ranking solutions shall be obtained. A more detailed treatment of the methods is available in [57].

5 Illustration for Decision Making on Supplier Selection

Every industry irrespective of its nature needs evolving a decision framework of choosing optimum suppliers. In general, the supplier selection procedure is a multi-step process comprising several attributes. The quality of the products and the effective functioning of the industry primarily depend on the choice of the suppliers. Jafari et al [58] discussed the implementation of both fuzzy and neuro fuzzy based optimization methods in industrial decision-making. Junyi et al [59] explored a systematic review of the applications MCDM based decision making methods in supplier selection. Stojcic et al [60] discoursed the diverse applications of different MCDM methods in sustainability engineering. Sahoo and Goswami [61,62] presented a comprehensive review of MCDM applications in supplier selection with special reference to sustainability and industry 4.0. The above-mentioned literature works demonstrate the applications of MCDM approaches in supplier selection with special focus on different aspects.

In general, let us consider a production industry which decides the selection of suppliers based on the criteria of Quality, Cost, Delivery time, Reliability and Sustainability. These criteria are also referred as attributes. However, the levels of these attributes are represented as attribute values to evolve a more comprehensive decisioning process. The decision-making problem considered for the study considers dominant attribute values to be the ideal values of attainment. The dominant attribute values of each of the considered attributes are Superior, Highly Competitive, Exceptional, Highly Reliable and Leading. The following Table 4. represents description of attribute and the attribute values of criteria.

Table 4. Attribute and Attribute Values

Attribute	Attribute values	Description
Quality A1	**Superior (A11)**	The attribute quality in supplier selection considers the quality of the products and quality of the service.
	High (A12)	
	Acceptable (A13)	
	Marginal (A14)	
	Poor (A15)	
Cost (A2)	**Highly Competitive (A21)**	The attribute cost refers to the expenditures incurred for products and service.
	Competitive (A22)	
	Average (A23)	
	Above Average (A24)	
	High (A25)	

Attribute	Attribute values	Description
Delivery Time (A3)	**Exceptional (A31)**	The attribute delivery time refers to the prompt delivery of the products and services.
	Reliable (A32)	
	Adequate (A33)	
	Inconsistent (A34)	
	Poor (A35)	
Reliability (A4)	**Highly Reliable (A41)**	Reliability refers to the consistency and the loyalty exhibited to the customers.
	Reliable (A42)	
	Generally Reliable (A43)	
	Inconsistent (A44)	
	Unreliable (A45)	
Sustainability (A5)	**Leading (A51)**	Sustainability refers to the environmental contributions of the suppliers which are measured by green services
	Strong (A52)	
	Average (A53)	
	Limited (A54)	
	Unsustainable (A55)	

The contradiction degrees between the attribute values with respect to the dominant attribute values are presented in Table 5.

Table 5. Contradiction Degrees between the attribute values and dominant attribute values

Dominant Attribute Value	Contradiction Degrees of other attribute values			
A11	A12	A13	A14	A15
	1/5	2/5	3/5	4/5
A21	A22	A23	A24	A25
	1/5	2/5	3/5	4/5
A31	A32	A33	A34	A35
	1/5	2/5	3/5	4/5
A41	A42	A43	A44	A45
	1/5	2/5	3/5	4/5
A51	A52	A53	A54	A55
	1/5	2/5	3/5	4/5

The combined plithogenic hypersoft representations are presented in Table 6., where the values presented in each of the cells represent the degree of apprutenance of the alterantives satifying the attribute values. Based on the expert's opinion, the degrees of apprutenance assume values of either fuzzy, intuitionistic and neutrosophic.

Table 6. Degrees of Appurtenance with respect to Combined Plithogenic Hypersoft sets

A1	S1	S2	S3	S4	S5
Superior	(0.2, 0.5, 0.7)	(0.3, 0.4, 0.6)	(0.7, 0.2)	0.6	(0.4, 0.2, 0.6)
High	(0.4, 0.3, 0.5)	(0.5, 0.2, 0.4)	(0.6, 0.2, 0.4)	(0.5, 0.2, 0.5)	(0.4, 0.3, 0.5)
Acceptable	(0.5, 0.3, 0.4)	(0.6, 0.2)	0.8	(0.5, 0.3, 0.4)	0.5
Marginal	(0.6, 0.4, 0.2)	0.5	(0.5, 0.4, 0.3)	(0.6, 0.3, 0.3)	(0.6, 0.4)
Poor	(0.4, 0.1)	(0.7, 0.3, 0.2)	(0.8, 0.3, 0.1)	(0.7, 0.2)	(0.8, 0.3, 0.1)
A2	S1	S2	S3	S4	S5
Highly Competitive	0.7	(0.3,0.5)	(0.5,0.4,0.6)	(0.3,0.6)	(0.5.0.3,0.5)

A1	S1	S2	S3	S4	S5
Competitive	(0.3,0.4	(0.4,0.3,0.5)	(0.5,0.3,0.5)	0.8	(0.4,0.4,0.5)
Average	(0.2,0.6)	(0.5,0.3,0.4)	0.6	(0.5,0.4,0.3)	(0.5,0.4)
Above Average	(0.6,0.4,0.3)	0.6	(0.7,0.4,0.2)	(0.7,0.3)	(0.4,0.3)
High	(0.8,0.3)	(0.7,0.4,0.2)	(0.8,0.3,0.2)	(0.8,0.4,0.1)	0.7
A3	S1	S2	S3	S4	S5
Exceptional	(0.2,0.5,0.7)	(0.3,0.5,0.6)	(0.4,0.4)	(0.4,0.3,0.6)	(0.3,0.5)
Reliable	0.8	(0.5,0.4,0.5)	(0.8,0.2)	(0.5,0.3,0.4)	(0.7,0.2)
Adequate	(0.5,0.3,0.4)	(0.3,0.4)	(0.6,0.4,0.3)	(0.6,0.4)	0.4
Inconsistent	(0.6,0.4)	0.6	(0.7,0.4)	(0.6,0.4,0.3)	(0.6,0.4,0.3)
Poor	(0.7,0.3)	(0.8,0.4)	(0.8,0.3,0.1)	(0.7,0.2)	(0.8,0.3,0.1)
A4	S1	S2	S3	S4	S5
Highly Reliable	(0.5,0.7)	(0.3,0.4,0.6)	(0.4,0.4,0.6)	(0.4,0.3,0.6)	0.7
Reliable	(0.4,0.4,0.5)	(0.4,0.2)	(0.5,0.3,0.5)	(0.5,0.3)	(0.4,0.4,0.5)
Generally Reliable	0.5	(0.5,0.3,0.4)	(0.6,0.3)	(0.5,0.3,0.3)	(0.5,0.4)
Inconsistent	(0.6,0.4,0.2)	(0.7,0.4,0.2)	(0.6,0.4,0.3)	(0.7,0.4)	(0.7,0.4,0.2)
Unreliable	(0.8,0.4,0.1)	(0.8,0.3,0.1)	(0.8,0.3)	(0.8,0.3,0.1)	(0.6,0.2)
A5	S1	S2	S3	S4	S5
Leading	(0.2,0.5,0.7)	(0.5,0.6)	(0.4,0.4,0.6)	(0.3,0.4,0.6)	(0.4,0.4,0.5)
Strong	(0.4,0.4,0.5)	(0.5,0.3)	0.5	(0.5,0.3,0.4)	(0.5,0.4,0.4)
Average	(0.5,0.2)	(0.5,0.4,0.4)	(0.6,0.3,0.3)	(0.4,0.3)	(0.5,0.4,0.3)
Limited	(0.6,0.4,0.3)	0.7	(0.7,0.4,0.2)	(0.6,0.4,0.2)	(0.7,0.4)
Unsustainable	(0.8,0.3,0.2)	(0.8,0.3,0.2)	0.8	(0.8,0.3,0.1)	(0.8,0.4)

In the above representations, the combination of fuzzy, intuitionistic and neutrosophic is used to reflect the degree of appurtenance of the alternatives with each of the attribute values subjected to the attributes. By using the formula of Plithogenic accuracy function (4) for combined plithogenic hypersoft sets, the following Plithogenic accuracy matrix Ap (5) is obtained which is rearranged to form the plithogenic decision matrix (Table 7.).

$$\text{Ap} = \begin{pmatrix} 0.5867 & 0.5733 & 0.98 & 0.64 & 0.66 \\ 0.68 & 0.56 & 0.8 & 0.58 & 0.6233 \\ 0.8933 & 0.6534 & 0.58 & 0.5733 & 0.53 \\ 0.38 & 0.3867 & 0.5266 & 0.4867 & 0.5733 \\ 0.5266 & 0.51 & 0.5933 & 0.4867 & 0.5199 \end{pmatrix} \tag{5}$$

Table 7. The Plithogenic decision making matrix

Attributes/ Alternatives	A1	A2	A3	A4	A5
S1	0.5867	0.68	0.8933	0.38	0.5266
S2	0.5733	0.56	0.6534	0.3867	0.51
S3	0.98	0.8	0.58	0.5266	0.5933
S4	0.64	0.58	0.5733	0.4867	0.4867
S5	0.66	0.6233	0.53	0.5733	0.5199

By applying the methods of TOPSIS, VIKOR, MAIRCA and ELECTRE as discussed in Table 3, the ranking results with respect to combined plithogenic representations are obtained as follows in Table 8.

Table 8 Ranking Results with respect to Combined Plithogenic Hypersoft sets

Alternatives	TOPSIS		VIKOR		MAIRCA		ELECTRE	
	Score	Rank	Score	Score	Score	Rank	Score	Rank
S1	0.44701	2	0.6542	3	0.79982	4	0.6542	3
S2	0.17939	5	0.8452	1	0.71011	1	0.8452	1
S3	0.61653	1	0.4523	5	0.91356	5	0.4523	5
S4	0.23847	4	0.5786	4	0.73782	2	0.5786	4
S5	0.36126	3	0.7463	2	0.78444	3	0.7463	2

The pictorial representation of the scores obtained using different MCDM methods is presented in Figure 3.

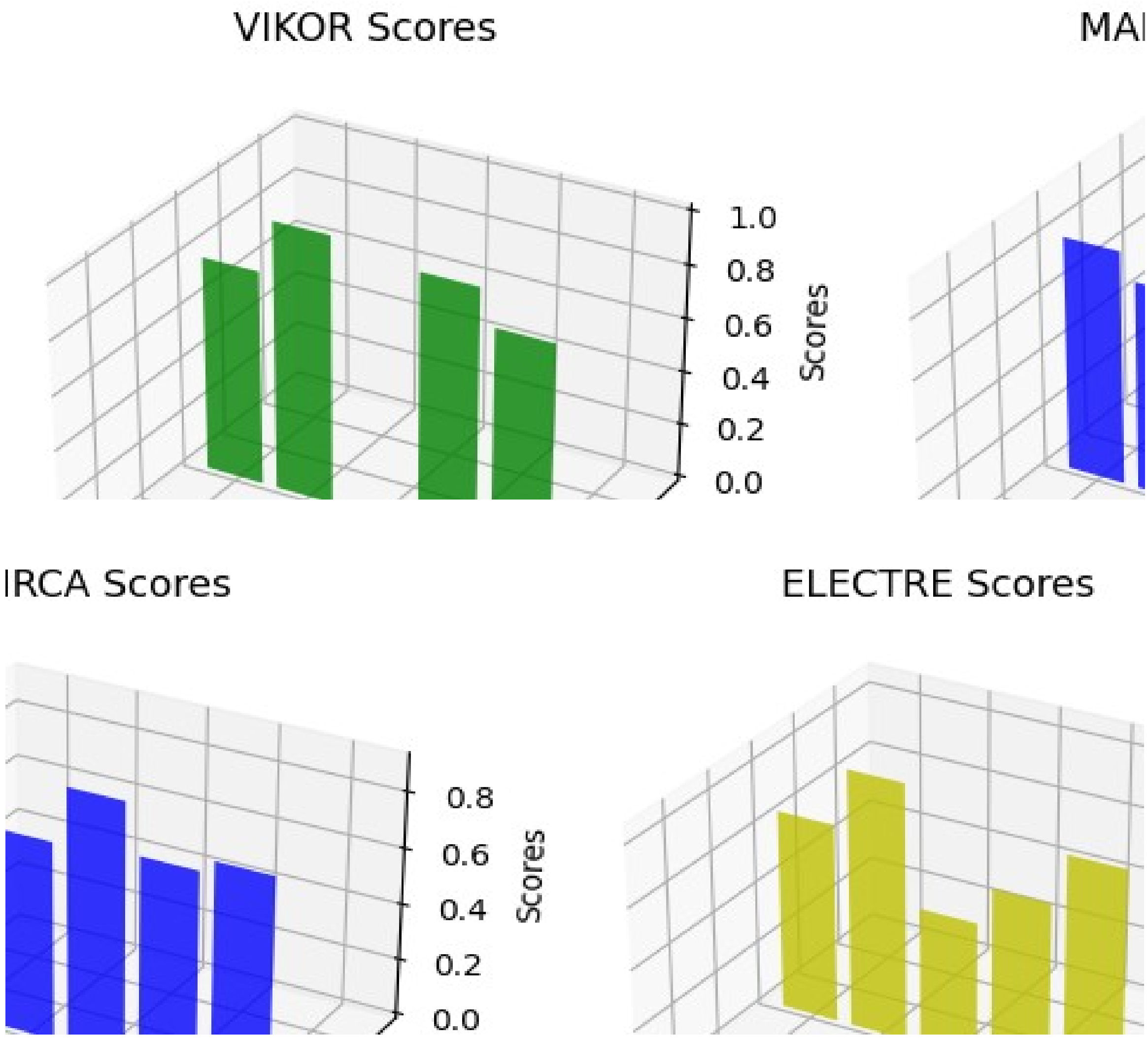

Figure 3. Scores of Different MCDM methods

The combined pictorial representation of the scores, combined pictorial representation of the ranks of different methods and the pictorial representation of both the ranks and scores are presented in Fig. 4, 5 and 6 respectively to have a better comparison between the results.

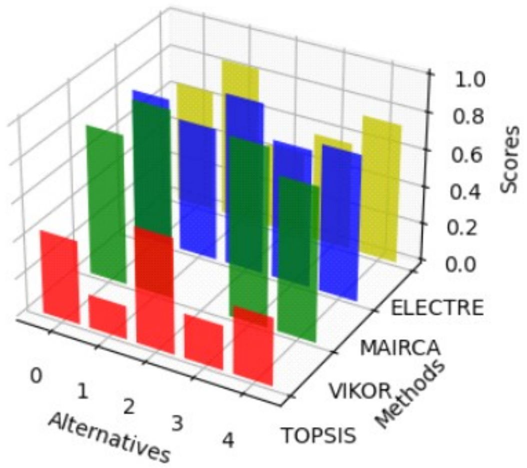

Figure 4. Combined Scores of the MCDM methods

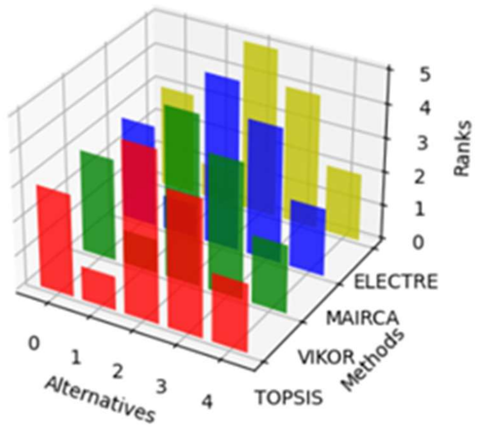

Figure 5. Combined Ranks of the MCDM methods

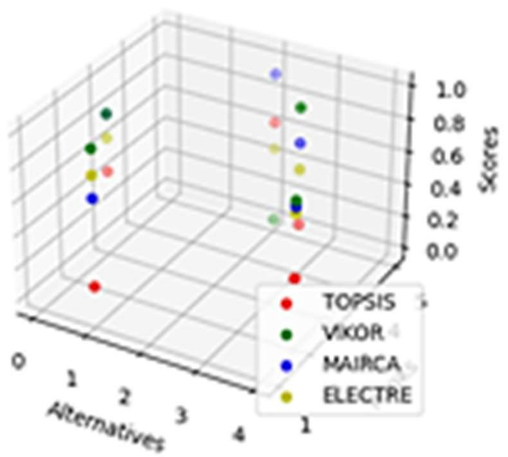

Figure 6. Combined Scores and Ranks of the MCDM methods

6 Sensitivity Analysis

This section analyses the effectiveness of combined plithogenic hypersofts sets, by considering a comparison with neutrosophic plithogenic hypersoft sets. The decision-making matrix obtained using only neutrosophic plithogenic hypersoft sets is of the form (6):

$$\begin{pmatrix} 0.5867 & 0.6333 & 0.6534 & 0.5266 & 0.5266 \\ 0.54 & 0.5867 & 0.6534 & 0.5199 & 0.5266 \\ 0.56 & 0.6 & 0.62 & 0.5266 & 0.5266 \\ 0.5733 & 0.5733 & 0.5733 & 0.4867 & 0.4867 \\ 0.56 & 0.5733 & 0.62 & 0.5266 & 0.5199 \end{pmatrix} \tag{6}$$

The rankings obtained using the same methods with respect to this decision-making matrix obtained using neutrosophic plithogenic representations are presented in Table 9.

Table 9 Ranking Results with respect to Neutrosophic Plithogenic Hypersoft sets

Alternatives	TOPSIS		VIKOR		MAIRCA		ELECTRE	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
S1	1.0000	1	1.0000	1	0.4640	5	0.7000	1
S2	0.5888	3	0.7861	2	0.4484	3	0.5500	3
S3	0.6134	2	0.4380	3	0.4500	4	0.6100	2
S4	0.2299	5	0.0000	5	0.4276	1	0.4800	5
S5	0.5110	4	0.3669	4	0.4448	2	0.5200	4

The ranking correlation between the rankings obtained from combined plithogenic hypersoft set representations are graphically presented in Figure 7 and Figure 8.

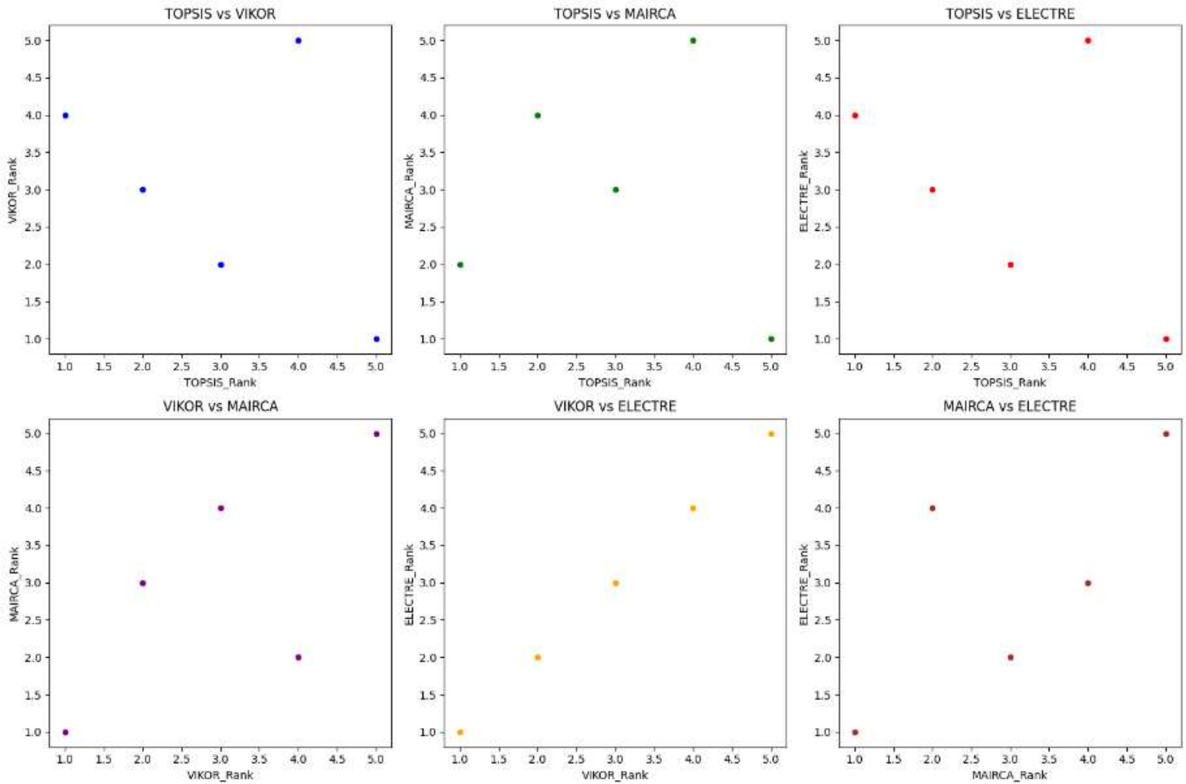

Figure 7. Correlation Results with respect to Combined Plithogenic Hypersoft sets

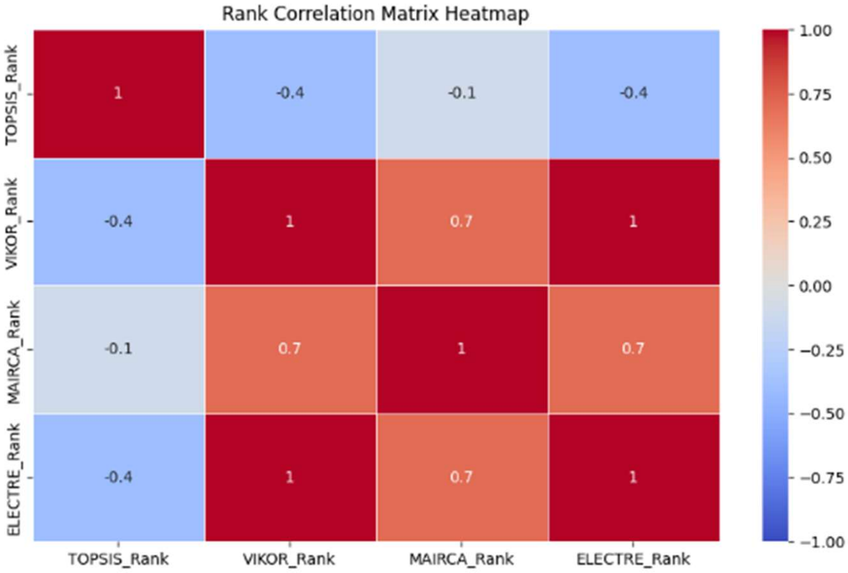

Figure 8. Correlation Results with respect to Combined Plithogenic Hypersoft sets

The ranking correlation between the rankings obtained from neutrosophic plithogenic hypersoft set representations are graphically presented in Figure 9. and Figure 10.

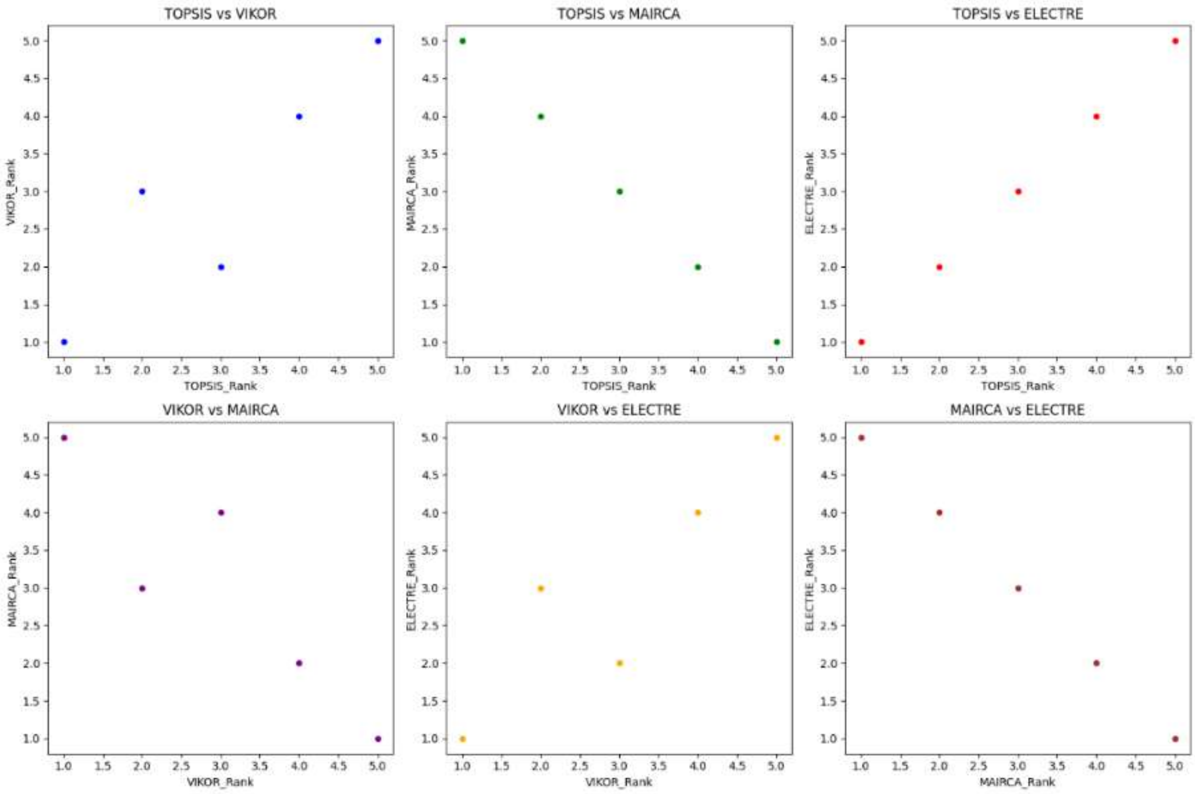

Figure 9. Correlation Results with respect to Neutrosophic Plithogenic Hypersoft sets

6.1 Inferences

- From Figure 7 and Figure 8, the correlation between the rankings of the MCDM methods with combined plithogenic hypersoft representations shall be analyzed based on the degree of correlation. The observations are presented in Table 10.

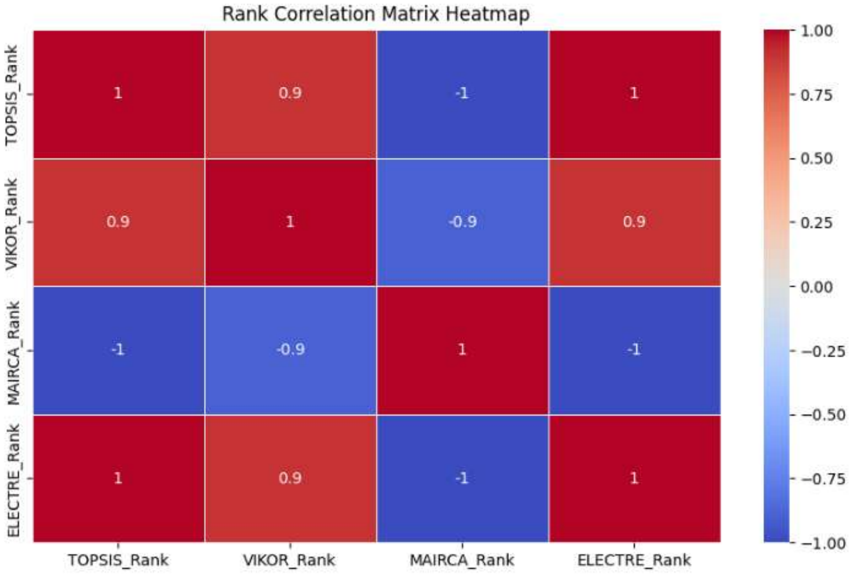

Figure 10. Correlation Results with respect to Neutrosophic Plithogenic Hypersoft sets

Table 10. Correlation between the MCDM methods with respect to Combined Plithogenic Hypersoft sets

Degree of the Correlation	MCDM methods
High Positive	TOPSIS and ELECTRE, VIKOR and MAIRCA
Moderate Positive	TOPSIS and VIKOR
Negligible	TOPSIS and MAIRCA

- From Figure 9. and Figure 10., the correlation between the rankings of the MCDM methods with neutrosophic plithogenic hypersoft representations shall be analyzed based on the degree of correlation. The observations are presented in Table 11.

Table 11. Correlation between the MCDM methods with respect to Neutrosophic Plithogenic Hypersoft sets

Degree of the Correlation	MCDM methods
High Positive	TOPSIS and VIKOR, ELECTRE and VIKOR
High Negative	TOPSIS and MAIRCA, VIKOR and MAIRCA

- The ranking results obtained from both the kinds of representations have consistency, where one of the alternatives occupies highest ranking position across the chosen methods. S2 in case of Combined Plithogenic and Si in case of Neutrosophic Plithogenic.
- There exist variations in rankings especially under neutrosophic representations, however S1 and S2 occupies consistent high rankings across both the methods exhibiting their robust performance.

7 Conclusion

This research work proposes a novel decision-making approach by integrating combined plithogenic hypersoft sets with different MCDM methods. The application of this hybrid approach to supplier selection problem exhibits the efficacy of this newly evolved method. The ranking results obtained using the methods of TOPSIS, VIKOR, MAIRCA and ELECTRE with combined representations are compared using neutrosophic representations. It is observed that the ranking results obtained using the combined plithogenic sets have less variations than the neutrosophic sets representations and this showcase the efficacy of combined representations. This research work has several industrial implictions as it addresses an intricate decisioning problem of supplier selection in general perspective. This decision framework is more comprehensive as it accomodates the core selection attribute of the suppliers. The criteria chosen for this study shall be modified based on any specific kind of suppliers. On other hand the attribute weights are assumed to be equal. This work shall be extended by computing the attribute weights using criterion computing used in general.Also, this research work shall be applied to other managerial decision-making circumstances using different MCDM methods. The combined plithogenic representations highly facilitate the decision makers to assign different degrees of appurtenance based on their intuitions and perceptions and hence evolving compatible decision-making models with convienent representations.

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