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Plithogenic Hypersoft based Plithogenic Cognitive Maps in Sustainable Industrial Development

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Abstract: Plithogenic Cognitive Maps (PCM) is a comprehensive decision tool discussed in diverse dimensions. The development of PCM models is indispensable in the domain of decision-making. This research work proposes theoretical framework of Plithogenic hypersoft sets (PHS) based PCM. This is a novel approach to make optimal decisions by considering several aspects simultaneously. The objective of this integrated approach is to make concurrent investigations on the interassociational impacts between the factors of the problem taken into account. The PHS based PCM is applied to a decision - making scenario of sustainable industrial development to demonstrate the significance of this PHS based PCM. The future directions and extensions of this work are also presented in this paper.

Keywords: Plithogenic Cognitive Maps, Plithogenic Hypersoft sets, Plithogenic accuracy function, sustainable industrial development.

1. Introduction

Smarandache [1] developed Plithogenic sets to generalize the representations ranging from crisp to neutrosophic forms. The development of this comprehensive kind of set is highly flexible in dealing with the attributes of different kinds. Plithogeny based applications are in increasing scales at recent times demonstrating a vivid picture of the efficacy of Plithogenic sets. The theory of hypersoft sets is developed to deal concurrently with varied attributes and it is discussed with Plithogenic sets. Smarandache is the pioneer in formulating both the theoretical aspects of Hypersoft sets and Plithogenic Hypersoft sets (PHS). Researchers have applied PHS to different decision-making situations involving complex patterns. Plithogenic Hypersoft sets are categorized as advanced kinds of sets as they are competent in handling intricated problems to design optimal solutions to the ranking kind of decision-making problems.

Cognitive Map structures are yet another robust decision tools applied to deal with the problems demanding intensive study on the factors and their relationships subjected to the context of the problem. As Plithogenic embraced theories give a holistic approach, Martin and Smarandache [2] extended the notion of cognitive maps to Plithogenic cognitive maps (PCM) and applied to distinct scenarios of decision making. Researchers have modified the theoretical framework of Plithogenic Cognitive Maps to formulate various versions of PCM models such as Plithogenic sub cognitive maps, induced PCM and many other. The decision-making approach of PCM is highly flexible in incorporating the requirements of the decision-makers. PCM models are initially developed only with the factors pertaining to the problem and then later, the attributes to which the factors are subjected are also considered together in developing the decision models. However, in these developments only the factor relationship subjected to only one attribute or the attribute values is considered for making analysis. This is identified as one of the limitations in factor considerations and hence this research work proposes the idea of integrating Plithogenic hypersoft sets to study the relationship between the factors by considering attributes in a concurrent manner. The objective of this research is to develop a highly comprehensive PCM decision model based on PHS representations to derive solutions to the complicated circumstance encompassing several factors and attributes demanding synchronized focus. The proposed model prototype is applied in analyzing the factors contributing to the sustainable industrial development.

The remaining contents of the paper are segmented into the following sections. The literature review is presented in section 2. The theoretical framework of PHS based PCM is outlined in section 3. The methodology of the proposed model is described in section 4. The application of the proposed framework in the industrial context is discoursed in section 5. The findings from the model are discussed in section 5. The summary of the paper is presented with future directions.

2. Review of Works

This section sketches out the contributions made in the domains of plithogenic cognitive maps and plithogenic hypersoft sets. The research gaps and the motivation behind this work is also outlined. Smarandache [18] developed the concept of hypersoft sets and then later extended to plithogenic hypersoft sets. Smarandache [21] laid a clear distinction between plithogenic sets and plithogenic hypersoft sets. Martin and Smarandache [8] discussed the applications of combined plithogenic hypersoft sets. Gayen et al [8] briefed on plithogenic hypersoft subgroups. Basumatary et al [16] discussed plithogenic neutrosophic hypersoft topological groups. Martin et al [10] introduced the concepts of extended plithogenic hypersoft sets and applied in Covid-19 decision making. Martin and Smarandache [11] illustrated the notion of concentric plithogenic hypergraph based on plithogenic hypersoft sets. Ahmad et al [12] developed a multi-criteria decision-making model based on plithogenic hypersoft sets. Rana et al [13] applied plithogenic fuzzy whole hypersoft sets and generalized plithogenic whole hypersoft sets in multi-attribute decision making with special reference to medical diagnosis. Majid et al [17] constructed a decision model for dam site selection using plithogenic multipolar fuzzy hypersoft sets. Dhivya and Lancy [19-20] conceptualized near plithogenic hypersoft sets and also focused on the notion of strong continuity. The research works on plithogenic hypersoft sets clearly state the applications of these sets in decision making.

Plithogenic cognitive maps are yet another exemplary for the extensive implication of Plithogenic sets. Martin and Smarandache [2] developed PCM for making optimal decisions by considering different factors and their respective contradiction degrees. Martin et al [3] conceptualized the notion of new plithogenic sub cognitive maps considering the mediating effects of the factors of medical diagnosis. Priya and Martin [4] introduced induced PCM with combined connection matrix to study the hitches of online learning system. Priya et al [5] applied PCM in making investigations on the spiritual intelligence of youth. Sujatha et al [6] developed a modified version of PCM approach in analyzing the novel corona virus. Angel et al [7] discoursed PCM model with linguistic contradiction degrees. The PCM decision models discuss the factors associated with the problem considering the degree of contradiction. However, these models determine the inter associational impacts between the factors considering only the factors one at a time. This is identified as one of the limitations of the PCM model. This research work proposes a PCM based decision model with plithogenic hypersoft sets to determine the aggregate inter associational impacts between the factors. This is a novel initiative of this research work and the integration of PHS into PCM framework unveils a comprehensive decision approach.

3. Theoretical Framework of PHS based PCM

PCM is generally considered to be a generalized representation of cognitive map structures. The PCM is also characterized as a directed graph with plithogenic weights considering different attributes in examining the interassociational impacts between factors of the study. Let us consider a problem of determining the interassociational impacts between the factors say F1, F2 and F3 considering the attributes say A1 with attribute values a11,a12,a13 and A2 with attribute values say a21,a22,a23 respectively.

The Plithogenic connection matrix is constructed with each of the cell values representing the interassociational impacts between the factors considering the Plithogenic hypersoft set representations of the form a11× a23, where a11 and a23 are the dominant attribute values with respect to the attributes A1 and A2.

Let us consider the reflection of the factors with respect to the attribute values as given in Table 1

Table 1 Association of Factors and Attribute values

	F1	**F2**	**F3**
a11	0.8	0.7	0.9
a12	0.6	0.5	0.7
a13	0.3	0.2	0.2
a21	0.4	0.3	0.3
a22	0.6	0.7	0.6
a23	0.9	0.9	0.8

The contradiction degrees between the dominant attribute value and other attribute values are presented in Table 2.

Table 2 Contradiction Degrees between the Attribute Values

a11	**a11**	a12	a13
	0	1/3	2/3
a23	a21	a22	**a23**
	2/3	1/3	0

The PHS based Plithogenic cognitive connection matrix representing the associational impacts between the factors are presented in Table 3

Table 3 Plithogenic Connection Matrix

	F1	**F2**	**F3**
F1	0	(a11,a23)	(a12,a22)
F2	(a13,a21)	0	(a11,a22)
F3	(a12,a22)	(a13,a23)	0

This PHS based connection matrix is represented for each of the attribute values in specific as follows.

A1	F1	F2	F3
F1	0	a11	a12
F2	a13	0	a11
F3	a12	a13	0

A2	F1	F2	F3
F1	0	a23	a22
F2	a21	0	a22
F3	a22	a23	0

A1	F1	F2	F3
F1	0	0.7	0.7
F2	0.3	0	0.9
F3	0.6	0.2	0

A2	F1	F2	F3
F1	0	0.9	0.6
F2	0.4	0	0.6
F3	0.6	0.9	0

The modified plithogenic connection matrices for each of the attribute values is obtained using the given formulae based on Plithogenic accuracy function stated by (1)

d(aij, Fg) +d(aik,Fg)* c(aij,aik) ………………..(1)

The modified Plithogenic connection matrix with respect to A1

A1	F1	F2	F3
F1	0	0.7	0.99
F2	0.83	0	0.9
F3	0.87	0.67	0

The cell (1,2) bears a11 in the plithogenic connection matric with respect to A1. The equivalent numerical value is 0.7. In this case the dominant attribute value is same as the cell value, whereas the equivalent numerical value for the cell (1,3) is computed using (1)

0.7 + 0.9* (1/3) ~ 0.99

The modified Plithogenic connection matrices are determined and the cognitive approach is applied to determine the interassociational impacts between the factors with respect to each of the dominant attribute values subjected to the attributes considered for study.

Let us consider the factor F1 to be in ON state

Let X = (1,0,0). This initial vector is passed onto the modified connection matrix and by performing the iterative procedure, the final state vector and the respective graphical representation is obtained in Fig.1.

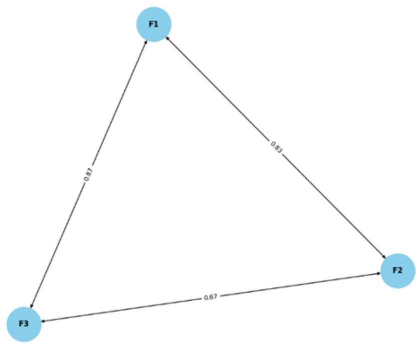

Fig.1 Interassociational Impacts between the Factors

4. Methodology

This section presents the sequential steps to be followed in developing PHS based PCM.

Step 1 : The framework begins with the formulation of decision problem with the consideration of concepts say F1,F2,..Fg and the attributes say A1,A2,..An pertaining to it.

Step 2 : The dominant attribute values say A1i, A2i ,.. Ani for each of the attributes are identified and the connection matrix with plithogenic hypersoft set representations is constructed.

Step 3: The connection matrix with respect to each of the attribute Aj is determined and then the modified plithogenic connection matrix is formulated using the plithogenic accuracy function of the form d(aij, Fg) +d(aik,Fg)* c(aij,aik). In this case d (aij, Fg) represents the degree of association between the attribute values and the factors, d(aik, Fg) id with respect to the dominant attribute values and c(aij, aik) is the degree of contradictions.

Step 4 : An initial state vector of the form (1 0 0 0 0 0..0) is considered and passed onto the connection matrix. The obtained vector is updated by assigning 1 to the values greater than 1 and -1 to the values lesser than 1.

Step 5 : The above step is repeated until the fixed point is obtained. The process the truncated after the vectors get converge to a state vector.

The above algorithmic procedure is presented graphically in Fig 2.

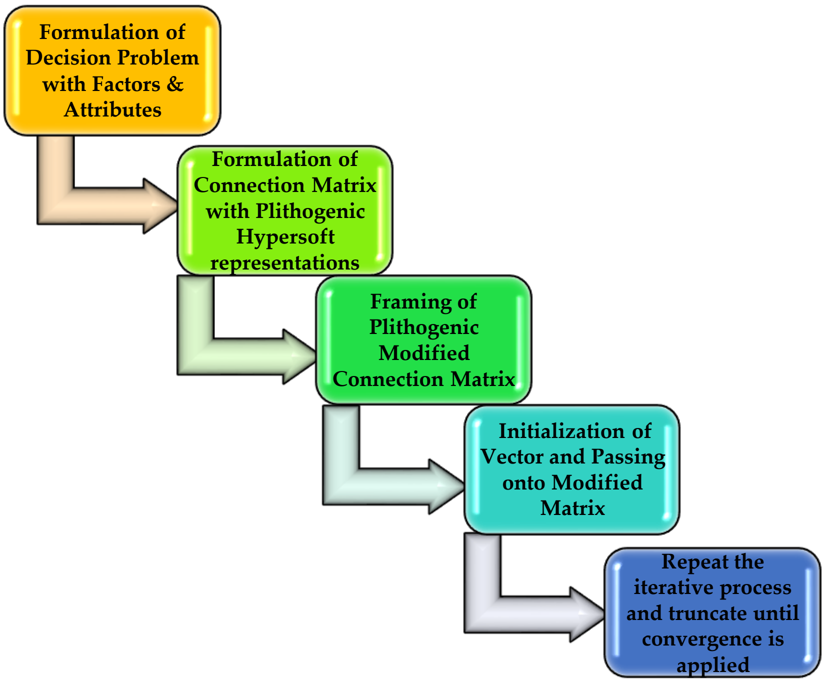

Fig 2: PHS based PCM Framework

5. Application of the Proposed Approach in Sustainable Industrial Development

This section applies the proposed framework in analyzing the factors contributing to the sustainable industrial development. Researchers have discussed about the strategies of institutionalizing sustainability in industrial development and few have focused on the modelling of sustainability. Dyrdonova [22] has developed a modelling framework of promoting sustainability in industries. Agbasi et al [23] considered soft computing and index-based methods in modelling the quality aspects of groundwater. The aforementioned recent research works state the significance of developing suitable models for studying the sustainability in industrial sectors. This section emphasizes that, the industrial sectors taking efforts in building the sustainability have to consider few significant attributes of sustainability into consideration. The attributes and the respective attribute values are presented in Table 4

Table 4 Attributes and their corresponding attribute values

Attributes	Attribute Values		
Efficiency in Resource Optimizations A1	Foundational a11	Enhanced a12	**Optimal a13**
Consistency in ensuring green initiatives A2	Primary a21	Standardized a22	**Integrated a23**
Economic Viability A3	Initial a31	Sustainable a32	**Profitable a33**
Innovative endeavours A4	Adoptive a41	Developmental a42	**Pioneering a43**
Compliance with environmental regulations A5	Baseline a51	Certified a52	**Exemplary a53**

The dominant attribute values are as highlighted in the above table.
Each of the attribute values represent the levels.

The factors considered in this decision-making problem are presented in Fig 3.

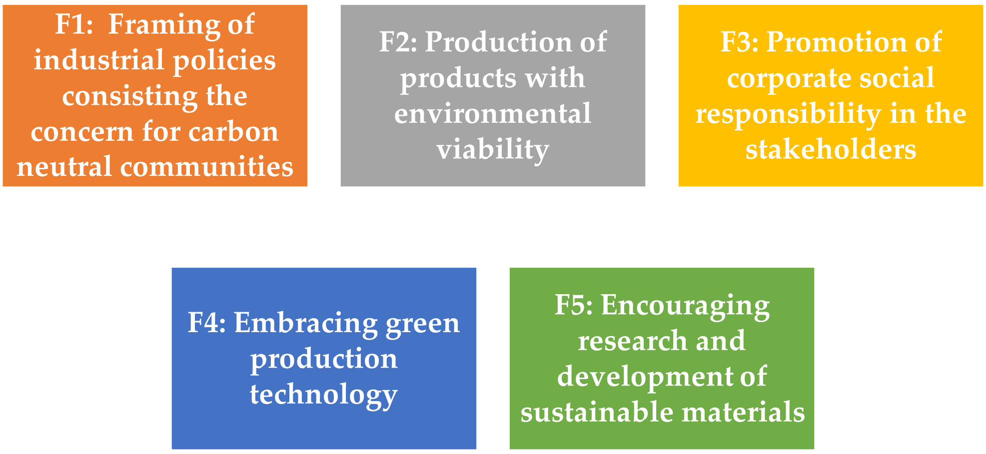

Fig 3: Factors considered for the decision-making problem

The sub factors for each of the factors are presented in Fig.4

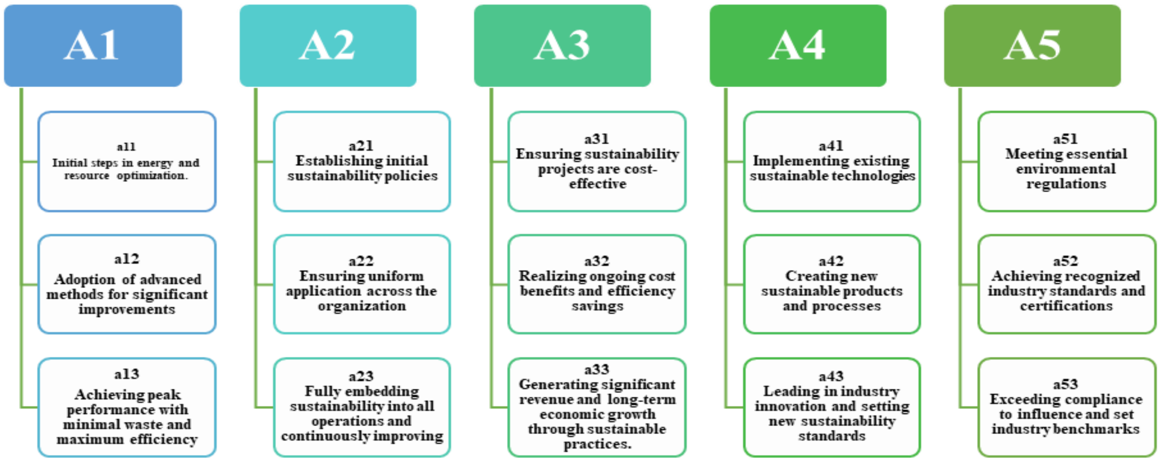

Fig 4. Sub-Factors considered for the decision-making problem

The experts are asked to give the possible associational impacts based on their perception, knowledge and experience and are presented in Table 5

Table 5 Expert's Opinion on Interassociational Impacts between the Factors

	F1	F2	F3	F4	F5
F1	0	(a12,a21,a32,a43, a52)	(a11,a22,a31,a42, a51)	(a13,a21,a33,a41, a52)	(a12,a23,a32,a43, a53)
F2	(a12,a21,a32,a 43,a52)	0	(a11,a21,a31,a42, a51)	(a12,a22,a32,a43, a52)	(a13,a23,a33,a41, a53)
F3	(a11,a22,a31,a 42,a51)	(a11,a21,a31,a42, a51)	0	(a12,a22,a32,a43, a52)	(a13,a23,a33,a41, a53)
F4	(a13,a21,a33,a 41,a52)	(a12,a22,a32,a43, a52)	(a12,a22,a32,a43, a52)	0	(a13,a23,a33,a41, a53)
F5	(a12,a23,a32,a 43,a53)	(a13,a23,a33,a41, a53)	(a13,a23,a33,a41, a53)	(a13,a23,a33,a41, a53)	0

Based on expert's opinion, the association between the attribute values and the factors are presented in Table 6.

Table 6 Attribute Values & Factors based on Expert's Opinion

Attribute values	F1	F2	F3	F4	F5
a11	0.3	0.4	0.3	0.5	0.4
a12	0.6	0.7	0.5	0.7	0.6
a13	0.9	0.9	0.7	0.9	0.8
a21	0.4	0.3	0.4	0.4	0.3
a22	0.7	0.6	0.6	0.7	0.5
a23	0.9	0.8	0.8	0.9	0.7
a31	0.3	0.4	0.3	0.4	0.5
a32	0.6	0.6	0.5	0.6	0.7
a33	0.8	0.8	0.7	0.8	0.9

a41	0.5	0.5	0.4	0.5	0.4
a42	0.7	0.7	0.6	0.8	0.7
a43	0.9	0.9	0.8	0.9	0.9
a51	0.4	0.3	0.2	0.5	0.4
a52	0.7	0.7	0.5	0.7	0.6
a53	0.9	0.9	0.7	0.9	0.8

These below values in Table 7-11 indicate the alignment of the factors with the attribute values

Table 7 Alignment of A1 Factor with the Attribute Values

A1	F1	F2	F3	F4	F5
F1	0	1	0.77	0.9	0.87
F2	0.9	0	0.77	1	0.8
F3	0.6	0.7	0	1	0.8
F4	0.9	1	0.73	0	0.8
F5	0.9	0.9	0.7	0.9	0

Table 8 Alignment of A2 Factor with the Attribute Values

A2	F1	F2	F3	F4	F5
F1	0	0.83	0.87	1	0.7
F2	1	0	0.93	1	0.7
F3	1	0.83	0	1	0.7
F4	1	0.87	0.87	0	0.7
F5	0.9	0.8	0.8	0.9	0

Table 9 Alignment of A3 Factor with the Attribute Values

A3	F1	F2	F3	F4	F5
F1	0	0.87	0.77	0.8	1
F2	0.87	0	0.77	0.87	0.9
F3	0.83	0.93	0	0.87	0.9
F4	0.8	0.87	0.73	0	0.9
F5	0.87	0.8	0.7	0.8	0

Table 10 Alignment of A4 Factor with the Attribute Values

A4	F1	F2	F3	F4	F5
F1	0	0.9	0.87	1	0.9
F2	0.9	0	0.87	0.9	1
F3	1	1	0	0.9	1
F4	1	0.9	0.8	0	1
F5	0.9	1	0.93	1	0

Table 11 Alignment of A5 Factor with the Attribute Values

A5	F1	F2	F3	F4	F5
F1	0	1	0.67	1	0.8
F2	1	0	0.67	1	0.8
F3	1	0.9	0	1	0.8
F4	1	1	0.73	0	0.8
F5	0.9	0.9	0.7	0.9	0

The contradiction degree between the factors and the dominant attribute values are given in the table 12

Table 12 Contradiction Degrees Between the Factors & The Dominant Attribute Values

	F1	F2	F3	F4	F5
A1(a13)	0.6	0.3	0.5	0.7	0.2
A2(a23)	0.4	0.2	0.5	0.5	0.6
A3(a33)	0.7	0.5	0.3	0.2	0.4
A4(a43)	0.3	0.5	0.4	0.1	0.5
A5(a53)	0.5	0.4	0.6	0.2	0.7

Let us consider the instantaneous vector X = (1 0 0 0 0) with the first factor in ON position.

The vector is passed on to the modified plithogenic connection matrix of A1 to find the fixed point of the system

X*P(A1) = (0.6 1 0.885 0.97 0.896) → (1 1 0.89 0.97 0.9) = X1

X1*P(A1) = (0.96 1 0.885 1 0.896) → (1 1 0.89 1 0.9) = X2

X2*P(A1) = (0.96 1 0.885 1 0.896) → (1 1 0.89 1 0.9) = X3

X2 = X3

Hence the fixed point is obtained.

Similarly, this instantaneous vector is passed on to each of the modified plithogenic connection matrix to obtain the fixed point.

6. Discussions

The similar approach is followed for all the other factors and the following table 13 is obtained as follows.

Table 13 Associational Impacts between the Factors

On Position of the Factors	Attribute	Associational Impacts				
		F1	F2	F3	F4	F5
F1 (10000)	A1 (a13)	1	1	0.89	1	0.9
	A2 (a23)	1	0.9	0.94	1	0.88
	A3 (a33)	1	0.94	0.84	0.85	1
	A4 (a43)	1	1	0.96	1	1
	A5 (a53)	1	1	0.89	1	0.94
F2 (01000)	A1 (a13)	0.96	1	0.89	1	0.87
	A2 (a23)	1	1	0.97	1	0.88
	A3 (a33)	0.96	1	0.84	0.9	0.98
	A4 (a43)	1	1	0.96	1	1
	A5 (a53)	1	1	0.89	1	0.94
F3 (00100)	A1 (a13)	0.96	1	1	1	0.87
	A2 (a23)	1	0.9	1	0.88	1
	A3 (a33)	0.95	0.97	1	0.9	0.97
	A4 (a43)	1	1	1	1	1
	A5 (a53)	1	1	1	1	0.94
F4 (00010)	A1 (a13)	0.96	1	0.89	1	0.87
	A2 (a23)	1	0.9	0.94	1	0.88
	A3 (a33)	0.95	0.94	0.81	1	0.97
	A4 (a43)	1	1	0.96	1	1
	A5 (a53)	1	1	0.89	1	0.94
F5 (00001)	A1 (a13)	0.96	0.99	0.88	0.99	1
	A2 (a23)	0.99	0.88	0.93	0.99	1
	A3 (a33)	0.96	0.92	0.81	0.84	1
	A4 (a43)	1	1	0.96	1	1
	A5 (a53)	0.99	0.98	0.88	0.99	1

The above table values shall be graphically represented in Fig.5-9 to visualize the associational impacts with respect to the on position of the factors

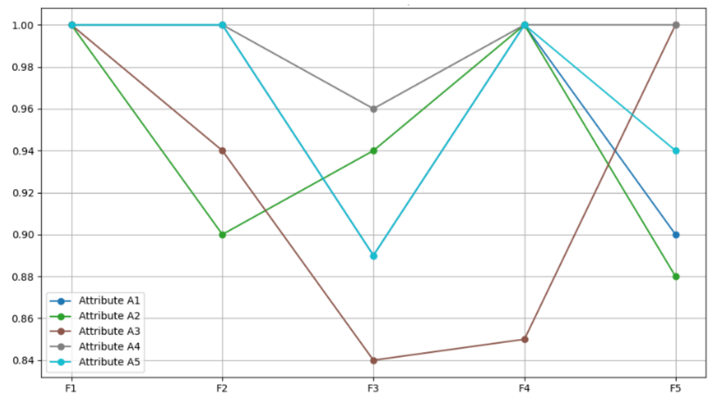

Fig.5 Visualization of the Associational Impacts with respect to ON position of F1

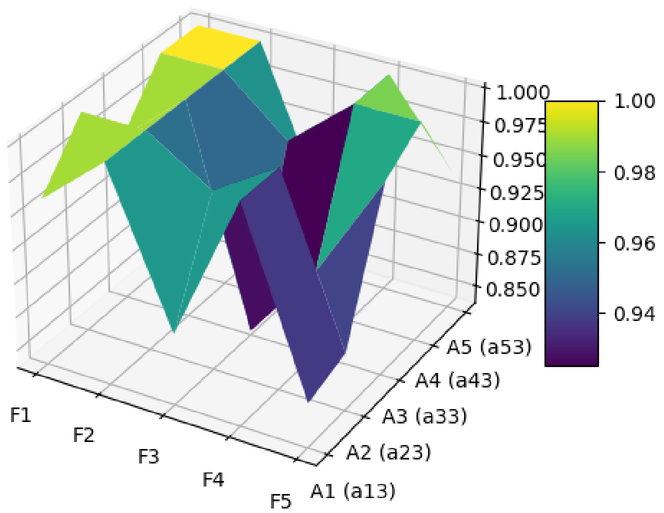

Fig.6 Visualization of the Associational Impacts with respect to ON position of F2

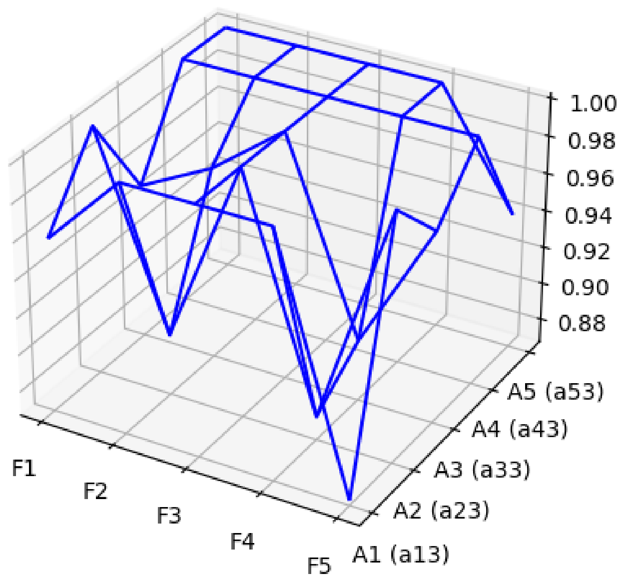

Fig.7 Visualization of the Associational Impacts with respect to ON position of F3

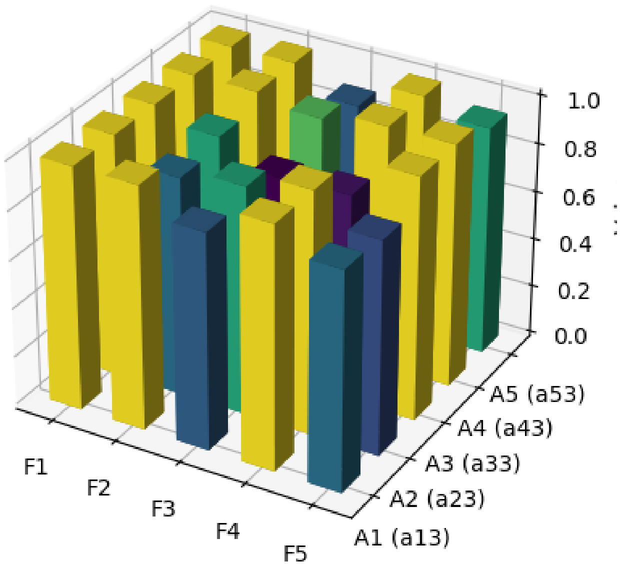

Fig.8 Visualization of the Associational Impacts with respect to ON position of F4

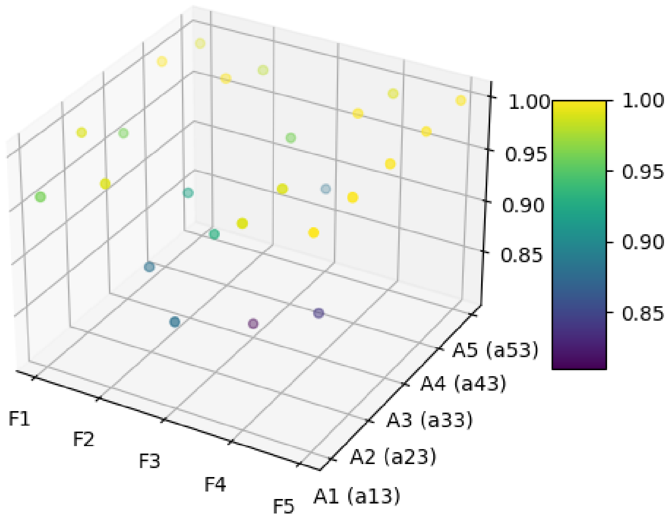

Fig.9 Visualization of the Associational Impacts with respect to ON position of F5

From the above table 13 and the figures 5-9, the interassociational impacts between the factors are determined by considering the attributes and the attribute values. The aggregate impacts between the factors with respect to the dominant attribute values are obtained using plithogenic hypersoft sets representation. The modified connection matrix obtained using plithogenic accuracy function facilitates in considering the degrees of contradiction between the attribute values and the feasibility of the attribute values with respect to the factors. The vector stating the aggregate impacts shall be determined by adding the vectors which will reflect the cumulative effects of one factor over another. The cumulative associational impacts of the factors F1,F2,F3,F4 and F5 with respect to each of the attributes A1 (a13),A(a23),A3(a33),A4(a43) and A5(a53) is presented in Fig.10

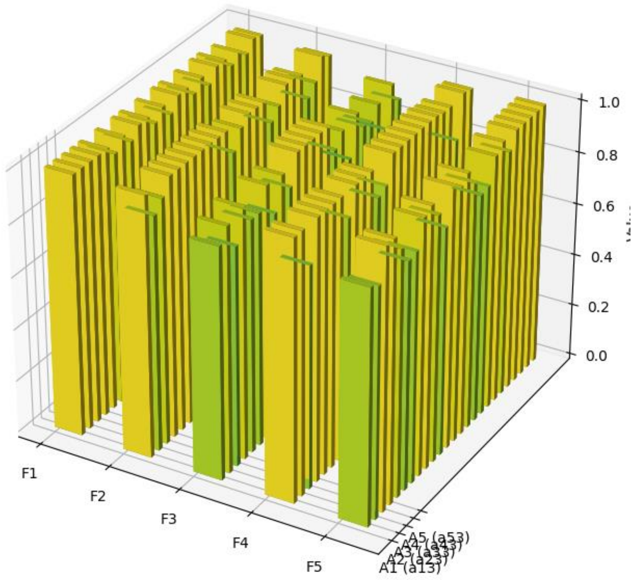

Fig.10 Aggregate Associational Impacts

Conclusion

This research work proposes a novel approach of PCM integrating plithogenic hypersoft sets representation. This novel initiative discloses new avenues of developing decision models. The proposed model is well substantiated with a decision-making problem on promoting the sustainability of industrial development by considering factors of different dimensions confined to attributes and their respective attribute values. This approach shall be extended with different kind plithogenic hypersoft sets. This new kind of decision-making framework is more flexible and robust in handling complex relationships.

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