Chapter

Plithogenic SWARA-TOPSIS Decision Making on Food Processing Methods with Different Normalization Techniques

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Abstract

Decision making (DM) is a process of choosing the optimal alternative with the maximum extent of criteria satisfaction. The challenging aspect in making optimal decisions is the suitable choice of multi-criteria decision-making (MCDM) methods that consider the initial input as the expert's opinion on criteria satisfaction by the alternatives. This initial decision-making matrix representation discriminates MCDM as fuzzy, intuitionistic, neutrosophic to handle the decision-making environment that is characterized by uncertainty, impreciseness, and indeterminacy, respectively. A generalized kind of representation by plithogenic sets optimizes the decision-making risks. This chapter aims in developing SWARA-TOPSIS with plithogenic representations and discusses the efficiency of this integrated approach over the method of TOPSIS with equal criterion weight. A comparative analysis of four different normalization techniques is likewise made. The proposed plithogenic integrated MCDM model is validated with the decision making on four food processing methods. The final ranks of the alternatives are also compared under the proposed plithogenic SWARA-TOPSIS and TOPSIS models with different normalization techniques. The results witness the efficiency of the proposed model over the existing models.

Keywords: optimality, MCDM, SWARS-TOPSIS, plithogeny

1. Introduction

Multi-criteria decision-making (MCDM) methods are classified into multi-attribute decision-making and multi-objective decision-making in which the former determines the optimal alternatives and the latter finds the optimal alternatives that optimize the objective. The MCDM methods comprise a sequence of steps to derive the optimal solution to the decision-making problem. DM is the system of choosing the best alternative satisfying all the criteria to a great extent with the expert's assist, but the crucial thing is finding the criterion weight. At some circumstances, the criterion weights are assumed to be equal but it is not so in all the cases. The criterion weight states the significance of criteria and henceforth, the calculation of criterion weight is very essential. There are many methods to find the criterion weights such as analytic hierarchical process (AHP), analytic network process (ANP), best worst method (BWM), full consistency method (FUCOM), and stepwise weight assessment ratio analysis (SWARA). The method of SWARA appears to be simple and flexible in comparison with other methods of determining the criterion weight based on human expertise and it has several applications in prioritizing sustainability indicators of energy systems [1]. The method of TOPSIS (the technique for order of preference by similarity to ideal solution) is commonly used to rank the alternatives as it yields the best results in comparison with other methods and it has been discussed in a fuzzy environment by Neelima et al. [2] and Ansari et al. [3]. Babak et al. [4] and Houssine et al. [5] discussed TOPSIS under intuitionistic fuzzy and neutrosophic [6] environments.

The method of SWARA was used in combination with crisp COPRAS [7], fuzzy COPRAS [8], crisp VIKOR [9, 10], neutrosophic VIKOR [11], WASPAS [12], Delphi [13], ARAS, GRA [14], TOPSIS in different decision-making setting. The integrated approach of SWARA-TOPSIS was inferred to yield better results based on the study on its applications in supplier selection [15], reducing ecological risk factors [16], prioritizing the failures in a solar panel system. This integrated approach was discussed in the environments of fuzzy [17], intuitionistic, and neutrosophic [18, 19]. Ahmet et al. [20], Miranda et al. [21], and Nazanin et al. [22] discussed different data normalization techniques. To give a comprehensive picture of representing the expert's opinion, this integrated approach is discussed under plithogenic environment in this paper, which is not explored so far to the best of the knowledge. At recent times, researchers develop novel plithogenic MCDM methods. In these plithogenic decision-making models, the plithogenic operators together with the contradiction degree are used to find the aggregate opinion of the experts regarding the criterion satisfaction rate of the alternatives.

In this research work, plithogenic SWARA-TOPSIS is developed by applying plithogenic intersection operator to the expert's opinion on the initial decision-making matrix. The efficiency of different normalization techniques of the weighted matrices is determined by applying them to two different cases. The first case is plithogenic TOPSIS with equal criterion weight, and the second is plithogenic SWAR-TOPSIS. The comparison of both the cases will certainly unveil the efficiency of the proposed approach. The remaining content is segmented as follows, Section 2 presents the methodology; the section consists of the application of the proposed method to the decision-making of food processing technology; Section 4 discusses the result and the last section concludes the work (**Table 1**).

AHP	analytic hierarchical process
ANP	analytic network process
ARAS	additive ratio assessment method
BWM	best worst method
COPRAS	complex proportional assessment
FUCOM	full consistency method
GRA	gray relational analysis
SWARA	stepwise weight assessment ratio analysis
TOPSIS	technique for order of preference by similarity to ideal solution
VIKOR	VlseKriterijuska Optimizacija. I Komoromisno Resenje
WASPAS	weighted aggregated sum product assessment

Table 1.
List of acronyms.

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2. Methodology

The method of plithogenic SWARA-TOPSIS is used to find the ranking of the alternatives. The steps involved are as follows:

Step 1: The initial decision-making matrix of order $u \times v$ with u alternatives and v criteria is constructed from the expert's perspective. This matrix consists of the criterion satisfaction by the alternatives, and the representation is made by using linguistic variables such as very high, high, moderate, low, and very low. The linguistic terms are not confined to these values alone. In general, a minimum of two expert's opinions is considered in framing the initial decision-making matrix. The aggregate expert's opinion is obtained using plithogenic intersection operators based on the representations (Fuzzy/intuitionistic/neutrosophic) of the linguistic variables.

Plithogenic Fuzzy Intersection $a \bigwedge_F b$.

Plithogenic Intuitionistic Intersection $(a_1, a_2) \wedge_{IFS} (b_1, b_2) = (a_1 \wedge_F b_1, a_2 \vee_F b_2)$

Plithogenic Neutrosophic Intersection $(a_1, a_2, a_3) \wedge_P (b_1, b_2, b_3) = \left(a_1 \vee_F b_1, \frac{1}{2}[(a_2 \wedge_F b_2) + (a_2 \vee_F b_2), a_3 \wedge_F b_3]\right)$

$$a \bigwedge_F b = ab, a \vee_F b = a + b - ab$$

Step 2: The criterion weights are obtained by the method of SWARA, which are as follows:

i. The criteria are arranged in descending order by the experts based on their significance.

ii. The relative importance of the criterion placed in (h-1)th position over hth gives the comparative importance of the average value s_h

iii. The relative weights w_j of the evaluation criteria is determined

$$w_h = \frac{q_h}{\sum_{k=1}^{v} q_k}$$

where q_j, the recalculated weight

$$q_h = \begin{cases} 1 & h = 1 \\ \frac{q_{h-1}}{k_h} & h > 1 \end{cases} \text{ and } k_h = \begin{cases} 1 & h = 1 \\ s_{h+1} & h > 1 \end{cases}$$

Step 3: After finding the criterion weights by the method of SWARA, the aggregate normalized weighted matrix $D = (d_{ih})$ is determined by using any of the normalization techniques before which the criteria are classified as benefit criteria and cost criteria, where the former must be maximized and the latter to be minimized. The four normalization techniques are shown in **Table 2**.

Step 4: The positive ideal solution $D^+ = \left(d_1^+, d_2^+, d_3^+, \ldots d_v^+\right) = \max (d_{ih})$ for benefit criteria and min (d_{ih}) for cost criteria. The negative ideal solution

$D^- = \left(d_1^-, d_2^-, d_3^-, \ldots d_v^-\right) = \min (d_{ih})$ for benefit criteria and max (d_{ih}) for cost criteria.

Normalization technique	Benefit criteria	Cost criteria
Linear scale transformation max method (NT1)	$\frac{x_{ih}}{x_{i\ max}}$	$\frac{x_{i\ min}}{x_{ih}}$
Linear scale transformation max-min method (NT2)	$\frac{x_{ih} - \min x_{ih}}{\max x_{ih} - \min x_{ih}}$	$\frac{\max x_{ih} - x_{ih}}{\max x_{ih} - \min x_{ih}}$
Linear scale transformation sum method (NT3)	$\frac{x_{ih}}{\sum_{i=1}^{u} x_i}$	$1 - \frac{x_{ih}}{\sum_{i=1}^{u} x_i}$
Vector-normalization method (NT4)	$\frac{x_{ih}}{\sqrt{\sum_{i=1}^{u} {x_{ih}}^2}}$	$1 - \frac{x_{ih}}{\sqrt{\sum_{i=1}^{u} {x_{ih}}^2}}$

Table 2.
Normalization techniques.

Step 5: F_i^+, the distance between the alternatives and the positive ideal solution F_i^- is the distance between the alternatives and the negative ideal solution is calculated as follows:

$$F_i^+ = \sqrt{\sum_{h=1}^{v} \left(d_h^+ - d_{ih}\right)^2}; i = 1, 2, \dots u$$

$$F_i^- = \sqrt{\sum_{h=1}^{v} \left(d_h^- - d_{ih}\right)^2}; i = 1, 2, \dots u$$

Step 6: The relative closeness to the ideal solution $R_i = \frac{F_i^-}{\left(F_i^+ - F_i^-\right)}$ is determined and the preferential ranking of the alternatives is made by the values of R_i. The alternatives with high scores are ranked from high to low.

3. Application to decision making on food processing methods

The proposed plithogenic SWARA-TOPSIS is illustrated with the decision making on the food processing technology. Food processing industries are the flourishing kind of industries in recent times. The lifestyle of the present generation has increased the consumption of processed food to a maximum extent. The consumers of processed food are quite steadily increasing as it is becoming inevitable. In general, these food industries employ various food processing technology for consumer acceptability and also introduce modern technology to meet the customer needs [23, 24].

The decision-making environment consists of four alternatives and five criteria that are stated as follows in **Table 3**.

The initial linguistic decision-making matrices given by two decision-makers are as follows:

Expert I

Methods Criteria	Z1	Z2	Z3	Z4	Z5
P1	M	H	M	H	M
P2	L	H	M	L	M
P3	M	H	VH	M	H
P4	VH	H	H	H	VH

Alternatives	Criteria
Chemical processing (P1)	Capital costs (Z1)
Biological processing (P2)	Microbial prevention (Z2)
Thermal processing (P3)	Time efficiency (Z3)
Non-thermal processing (P4)	Nutrients conservativeness (Z4)
	Longevity of shelf life (Z5)

Table 3.
Alternatives and criteria of the decision-making environment.

Linguistic terms	Neutrosophic representations
Very High (VH)	(0.95, 0.1, 0.1)
High (H)	(0.8, 0.2, 0.1)
Moderate (M)	(0.5, 0.5, 0.5)
Low (L)	(0.3, 0.7, 0.8)
Very Low (VL)	(0.1, 0.9, 0.9)

Table 4.
Quantification of linguistic terms.

Expert II

Methods Criteria	Z1	Z2	Z3	Z4	Z5
P1	H	VH	H	H	M
P2	VL	M	H	L	M
P3	H	VH	H	M	VH
P4	VH	VH	VH	H	H

Neutrosophic representations are used to quantify the linguistic values as given in **Table 4**.

The plithogenic aggregated expert decision matrix is

Methods Criteria	Z1	Z2	Z3	Z4	Z5
P1	0.397	0.5766	0.397	0.5678	0.3076
P2	0.073	0.397	0.397	0.167	0.3076
P3	0.397	0.5766	0.5766	0.3076	0.5766
P4	0.579	0.5766	0.5766	0.5678	0.5766

Case I: The criterion weights are assumed to be equal and the alternatives are ranked based on the scores of R_i obtained by using four different normalization techniques.

Normalization technique		Normalized weighted decision-making matrix					R_i	Rank
		Z1	Z2	Z3	Z4	Z5		
Linear scale transformation max method	P1	0.2	0.137704	0.196948	0.106694	0.2	0.664386	3
	P2	0.137704	0.137704	0.057926	0.106694	0.137704	0	4
	P3	0.2	0.2	0.106694	0.2	0.2	0.700953	2
	P4	0.2	0.2	0.196948	0.2	0.2	1	1
Linear scale transformation max-min method	P1	0.071937	0.2	0	0.2	0	0.51547	3
	P2	0.2	0	0	0	0	0	4
	P3	0.071937	0.2	0.2	0.07016	0.2	0.716921	2
	P4	0	0.2	0.2	0.2	0.2	1	1
Linear scale transformation sum method	P1	0.14509	0.054222	0.040776	0.070525	0.034789	0.613146	2
	P2	0.189903	0.037333	0.040776	0.020743	0.034789	0	4
	P3	0.14509	0.054222	0.059224	0.038206	0.065211	0.602772	3
	P4	0.119917	0.054222	0.059224	0.070525	0.065211	1	1
Vector-normalization method	P1	0.101952	0.107303	0.0802	0.129641	0.066565	0.605883	3
	P2	0.181971	0.07388	0.0802	0.03813	0.066565	0	4
	P3	0.101952	0.107303	0.116482	0.070232	0.124776	0.607144	2
	P4	0.057003	0.107303	0.116482	0.129641	0.124776	1	1

Case II: The criterion weights are obtained by using the method of SWARA: Expert I

Criteria	S_h	K_h	W_h	q_h
Z1	1	1	1	0.288
Z3	0.25	1.25	0.8	0.23
Z2	0.3	1.3	0.62	0.179
Z4	0.15	1.15	0.54	0.156
Z5	0.07	1.07	0.51	0.147

Expert II

Criteria	S_h	K_h	W_h	q_h
Z1	1	1	1	0.33
Z3	0.35	1.35	0.74	0.24
Z2	0.4	1.4	0.53	0.17
Z4	0.25	1.25	0.42	0.14
Z5	0.17	1.17	0.36	0.12

Criteria	Z1	Z2	Z3	Z4	Z5
Weight	0.31	0.24	0.17	0.15	0.13

Normalization technique		Normalized weighted decision-making matrix					R_i	Rank
		Z1	Z2	Z3	Z4	Z5		
Linear scale transformation max method	P1	0.057002	0.24	0.117048	0.147711	0.069351	0.922045	3
	P2	0.31	0.165245	0.117048	0.043444	0.069351	0	4
	P3	0.057002	0.24	0.17	0.080021	0.13	0.940439	2
	P4	0.039084	0.24	0.17	0.147711	0.13	1	1
Linear scale transformation max-min method	P1	0.111502	0.24	0	0.15	0	0.672361	3
	P2	0.31	0	0	0	0	0	4
	P3	0.111502	0.24	0.17	0.05262	0.13	0.869149	2
	P4	0	0.24	0.17	0.15	0.13	1	1
Linear scale transformation sum method	P1	0.22489	0.065067	0.03466	0.052894	0.022613	0.754312	1
	P2	0.29435	0.0448	0.03466	0.015557	0.022613	0	4
	P3	0.22489	0.065067	0.05034	0.028655	0.042387	0.105651	3
	P4	0.185871	0.065067	0.05034	0.052894	0.042387	0.291429	2
Vector-normalization method	P1	0.158026	0.128763	0.06817	0.097231	0.043267	0.749931	2
	P2	0.282055	0.088656	0.06817	0.028597	0.043267	0	4
	P3	0.158026	0.128763	0.099009	0.052674	0.081105	0.425359	3
	P4	0.088355	0.128763	0.099009	0.097231	0.081105	0.85551	1

4. Results

The results obtained in both the cases are summarized as follows in **Table 5**, and the relative closeness scores under both the cases are presented in **Figures 1** and **2**.

Based on the rankings of the alternatives obtained under both the cases, it clearly gives the preferential ranking of the alternatives. In almost all the cases, nonthermal

Normalization technique	Case I	Case II
Linear scale transformation max method	P4 > P3 > P1 > P2	P4 > P3 > P1 > P2
Linear scale transformation max-min method	P4 > P3 > P1 > P2	P4 > P3 > P1 > P2
Linear scale transformation sum method	P4 > P1 > P3 > P2	P1 > P4 > P3 > P2
Vector-normalization method	P4 > P3 > P1 > P2	P4 > P1 > P3 > P2

Table 5.
Ranking of the alternatives under cases I and II.

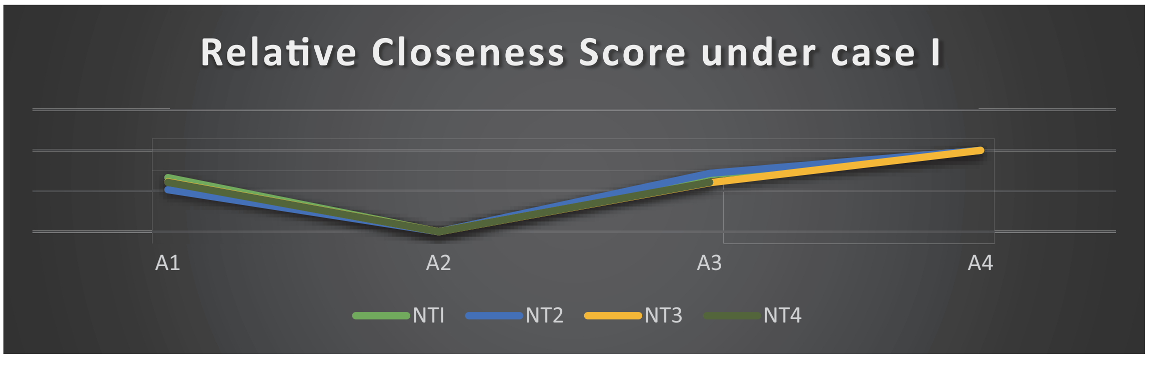

Figure 1.
Relative Closeness Score under case I.

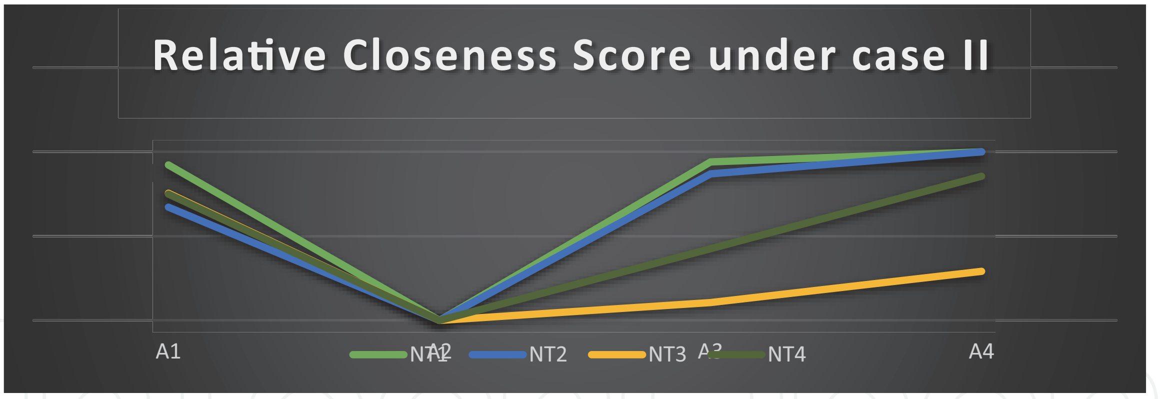

Figure 2.
Relative Closeness Score under case II.

processing technology acquires the first preference and chemical processing technology acquires the last preference. This ranking is validated under both the cases when various normalization techniques are used. The aggregate decision matrix obtained by using the plithogenic aggregate operators adds to the consistency of the proposed model. The ranking results differ only in both the cases under the normalization technique of the linear scale transformation sum method.

5. Conclusion

An integrated plithogenic SWARA-TOPSIS decision-making model is developed in this paper. A comparative analysis of various normalization techniques under two cases is made to determine the most preferred and least preferred food processing technology. The application of plithogenic to such a hybrid method is the novelty of this decision-making model. The proposed model shall be extended by using other plithogenic kinds of aggregate operators. This research work will certainly encourage the researchers to explore the applications of the proposed approach in various dimensions. The results obtained will also benefit the decision-makers in making an optimal selection on food processing technology.

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