Octa-Hexa fuzzy PROMTHEE for ranking the feasible industrial waste management methods

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Abstract

Environmental researchers are alarming the world about the dreadful effects of eco-degradation and emphasize that waste management is the need of the hour. Every nation has commenced to take efforts at different scales to make the universe green. Industries rank first in generating waste of all forms which is quite inevitable but, it can be mitigated by the implementation of suitable waste management methods. Protection of the environment from the effects of waste is the social responsibility of the medium and large scale industries. The present challenge of these industries is the selection of feasible waste management method to accomplish the task of environmental conservation. This research work mainly aims in ranking the feasible waste management methods for the benefit of the industrial sectors in the context of promoting environmental sustainability. A novel Fuzzy PROMTHEE (The Preference Ranking Organization method for Enrichment Evaluation) decision making model with the combination of octagonal and hexagonal fuzzy representations of linguistic variables is proposed in this paper. The results obtained are based on the criteria and the data of the predominantly used industrial waste management methods intended by the decision makers.

Keywords: *Octa-Hexa, fuzzy, PROMTHEE, industry, waste management.*

Introduction

Industrialization has brought economic profits and environmental dilapidation. The societal concern of an industry lies in shielding the surroundings from waste. Industries banish the waste without processing which decays the environmental sustainability. This negligent act has polluted the water sources, land and air to great extent and paved way for terrible disasters. The pollsters in the field of environmental management are making extensive study on the future status of the environment subjected to present conditions. The results are frightening and the people must be ready to live in the era of 'zero day' where the living organism will perish and leave no trace of its existence. To avert such happenings, waves of green alarms of making the planet turn greener are seen everywhere in terms of legal frames by the government and initiatives by non- governmental organization. The stern enforcement of environmental regulations has made the industries to practice waste management methods, but the practical problem is the selection of suitable method which is quite a challenging task for the decision makers. This research work formulates a decision making model of choosing a suitable waste management method subjected to certain criteria.

[1] PROMTHEE is one of the methods of multi-criteria decision analysis which binds up two aspects one is criteria and the other is the preference value. It is highly significant than other methods such as SMART (Simple Multi- Attribute Rating Technique), AHP (Analytic Hierarchy Process), ANP (Analytic Network Process), AIRM (Aggregated Indices Randomization Method), DEA (Data Envelop Analysis), ER (Evidence Reasoning Approach). The method of PROMTHEE has been applied in several scenarios for making decisions. To mention a few, [5]Kodikara in the evaluation of the alternatives of the operating rules for urban water supply problem. Wang, Yang [7]and Lin [6] in the problems of outsourcing. But this method has demerits of vagueness and uncertainty that hurdles the decision making. To resolve the problems of impreciseness Fuzzy PROMTHEE was developed by Ho [1]. This method has been extensively used by several researchers. Bilsel [1] has used Fuzzy PROMTHEE method in ranking the web sites for quality evaluation of hospital. Goumas [4] applied this method in ranking alternative energy exploitation projects. Chou [2] has used in evaluating suitable ecotechnology method. Eleveli [3] has employed this method in logistics freight center locations decision. In all these applications, triangular and trapezoidal fuzzy numbers are used to quantify the linguistic variables. But in this paper hexagonal and octagonal fuzzy numbers are used for quantifying the linguistic variables, an inventive effort of this research work. This work mainly aims in selecting the feasible waste management method with the application of higher order fuzzy numbers. The Octa-Hexa Fuzzy PROMTHEE method is applied to the decision making environment of ranking industrial waste management methods.

The paper is structured as follows: section 2 presents the methodology; section 3 encompasses the application of the proposed methodology to the problem considered; section 4 discusses the results and the last section concludes the paper.

2. Methodology

The procedure followed in this methodology is presented sequentially as follows:

1. The degree of satisfaction of the primary methods used by the industries for waste management to the criteria considered are represented using linguistic variables and later quantified by Octagonal fuzzy numbers.
2. The decision maker’s preference value to each criterion is also represented by linguistic variables which are quantified by Hexagonal fuzzy numbers.
3. The weight w_j of each criterion is calculated by normalizing the values of decision maker’s preference value to each criterion and using graded mean.

4. The comparison of the alternative methods namely a and b is obtained using
   P_j (a,b) = f_j (b) – f_j (a).
5. The positive and negative out ranking flows are determined.
   $\Phi^+ (a) = \frac{1}{(n-1)}\sum_{x\in A}\tilde{\lambda}(a,x)$, $\Phi^- (a) = \frac{1}{(n-1)}\sum_{x\in A}\tilde{\lambda}(x,a)$
   Where $\tilde{\lambda}(a,b)=\sum_{j=1}^{c} w_j P_j(a,b), \tilde{\lambda}(b,a)=\sum_{j=1}^{c} w_j P_j(b,a)$
   c is the number of criteria
6. The ranking is made with the values of Φ (a) = Φ^+ (a) - Φ^- (a).

3. Application of the Proposed Methodology

The adaptation of the proposed method is presented as below. Table 1 and 2 presents the criteria value and the preference value in terms of linguistic variables. Table 3 & 4 represents the octagonal and hexagonal representation of linguistic variables.

Table.1. Waste Management method's Data

Methods/criteria	Bio-friendly	Economically Feasible	Time Effective	Consistency	Monetary yield
Segregation M1	H	H	M	M	L
Composting M2	L	H	H	L	L
Landfill M3	H	L	L	H	H
Recycling M4	M	M	L	M	M
Incineration M5	H	M	M	M	L
Biogas Technology M6	M	L	L	H	H

Table.2. Preference to Criteria by the Decision maker

Decision Maker	Criteria				
	Bio-friendly	**Economically Feasible**	**Time Effective**	**Consistency**	**Monetary yield**
D1	HE	LE	ME	VHE	VLE
D2	VHE	HE	ME	LE	VLE

D3	ME	VHE	HE	ME	LE
D4	LE	ME	VHE	VLE	HE
D5	HE	LE	VLE	ME	VHE

Table.3. Fuzzy & Crisp representation of Octagonal fuzzy numbers

Low	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)	0.18
Medium	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	0.48
High	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	0.78

Table.4.The Hexagonal quantification of linguistic terminologies both in terms of fuzzy & Crisp

Very less essential	(0,0.05,0.1,0.15,0.2,0.25)	0.125
Less essential	(0.15,0.2,0.25,0.3,0.35,0.4)	0.275
Moderately essential	(0.3,0.35,0.4,0.45,0.5,0.55)	0.425
Highly essential	(0.45,0.5,0.55,0.6,0.65,0.7)	0.575
Very highly essential	(0.65,0.7,0.75,0.8,0.9,1)	0.8

The Octagonal and Hexagonal representation of Table 1 & 2 are presented in Table 5 & 6 respectively

Table. 5. Octagonal Representation of Waste Management method's Data

Methods/ Criteria	**Bio-friendly**	**Economically Feasible**	**Time Effective**	**Consistency**	**Monetary yield**
Segregation M1	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)
Composting M2	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)
Landfill M3	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)
Recycling M4	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)
Incineration M5	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	(0.3,0.35,0.4,0.45,0.5,0.55,0.6,0.65)	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.35)
Biogas Technology	(0.3,0.35,0.4,0.45,0.5,	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.3	(0,0.05,0.1,0.15,0.2,0.25,0.3,0.3	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)	(0.6,0.65,0.7,0.75,0.8,0.85,0.9,1)

M6	0.55,0.6,0.65)	5)	5)		

Table.6. Hexagonal Representation of Preference to Criteria by the Decision maker

Decision Maker	**Criteria**				
	Bio-friendly	**Economically Feasible**	**Time Effective**	**Consistency**	**Monetary yield**
D1	(0.45,0.5,0.55,0.6,0.65,0.7)	(0.15,0.2,0.25,0.3,0.35,0.4)	(0.3,0.35,0.4,0.45,0.5,0.55)	(0.65,0.7,0.75,0.8,0.9,1)	(0,0.05,0.1,0.15,0.2,0.25)
D2	(0.65,0.7,0.75,0.8,0.9,1)	(0.45,0.5,0.55,0.6,0.65,0.7)	(0.3,0.35,0.4,0.45,0.5,0.55)	(0.15,0.2,0.25,0.3,0.35,0.4)	(0,0.05,0.1,0.15,0.2,0.25)
D3	(0.3,0.35,0.4,0.45,0.5,0.55)	(0.65,0.7,0.75,0.8,0.9,1)	(0.45,0.5,0.55,0.6,0.65,0.7)	(0.3,0.35,0.4,0.45,0.5,0.55)	(0.15,0.2,0.25,0.3,0.35,0.4)
D4	(0.15,0.2,0.25,0.3,0.35,0.4)	(0.3,0.35,0.4,0.45,0.5,0.55)	(0.65,0.7,0.75,0.8,0.9,1)	(0,0.05,0.1,0.15,0.2,0.25)	(0.45,0.5,0.55,0.6,0.65,0.7)
D5	(0.45,0.5,0.55,0.6,0.65,0.7)	(0.15,0.2,0.25,0.3,0.35,0.4)	(0,0.05,0.1,0.15,0.2,0.25)	(0.3,0.35,0.4,0.45,0.5,0.55)	(0.65,0.7,0.75,0.8,0.9,1)

The crisp representation of Table 5 & 6 are presented in Table 7 & 8 respectively

Table. 7. Crisp Representation of Waste Management method's Data

Methods/criteria	**Bio-friendly**	**Economically Feasible**	**Time Effective**	**Consistency**	**Monetary yield**
M1	0.78	0.78	0.48	0.48	0.18
M2	0.18	0.78	0.78	0.18	0.18
M3	0.78	0.18	0.18	0.78	0.78
M4	0.48	0.48	0.18	0.48	0.48
M5	0.78	0.48	0.48	0.48	0.18
M6	0.48	0.18	0.18	0.78	0.78

Table.8. Crisp Representation of Preference to Criteria by the Decision maker

Decision Maker	**Criteria**				
	Bio-friendly	**Economically Feasible**	**Time Effective**	**Consistency**	**Monetary yield**
D1	0.575	0.275	0.425	0.8	0.125
D2	0.8	0.575	0.425	0.275	0.125
D3	0.425	0.8	0.575	0.425	0.275
D4	0.275	0.425	0.8	0.125	0.575
D5	0.575	0.275	0.125	0.425	0.8

Table.9. presents the weight of each criterion

Table.9. Computation of criteria's weight

Decision Maker	Criteria				
	Bio-friendly	**Economically Feasible**	**Time Effective**	**Consistency**	**Monetary yield**
D1	0.26	0.13	0.19	0.36	0.05
D2	0.36	0.26	0.19	0.13	0.05
D3	0.19	0.36	0.26	0.05	0.13
D4	0.13	0.19	0.36	0.05	0.26
D5	0.26	0.13	0.05	0.19	0.36
Maximum	0.36	0.36	0.36	0.36	0.36
Minimum	0.13	0.13	0.05	0.05	0.05
Average	0.24	0.214	0.21	0.156	0.17
Graded Mean	0.24	0.23	0.2	0.18	0.19

The preference values of the alternatives are presented in Table.10.

Table.10. Preference values of the alternatives

Pair of Alternatives	Bio-friendly	Economically Feasible	Time Effective	Consistency	Monetary yield
M1,M2	-0.6	0	0.3	-0.3	0
M1,M3	0	-0.6	-0.3	0.3	0.6
M1,M4	-0.3	-0.3	-0.3	0	0.3
M1,M5	0	-0.3	0	0	0
M1,M6	-0.3	-0.6	-0.3	0.3	0.6
M2,M1	0.6	0	-0.3	0.3	0
M2,M3	0.6	-0.6	-0.6	0.6	0.6
M2,M4	0.3	-0.3	-0.6	0.3	0.3
M2,M5	0.6	-0.3	-0.3	0.3	0
M2,M6	0.3	-0.6	-0.6	0.6	0.6
M3,M1	0	0.6	0.3	-0.3	-0.6
M3,M2	-0.6	0.6	0.6	-0.6	-0.6
M3,M4	-0.3	0.3	0	-0.3	-0.3
M3,M5	0	0.3	0.3	-0.3	-0.6
M3,M6	-0.3	0	0	0	0
M4,M1	0.3	0.3	0.3	0	-0.3
M4,M2	-0.3	0.3	0.6	-0.3	-0.3

M4,M3	0.3	-0.3	0	0.3	0.3
M4,M5	0.3	0	0.3	0	-0.3
M4,M6	0	-0.3	0	0.3	0.3
M5,M1	0	0.3	0	0	0
M5,M2	-0.6	0.3	0.3	-0.3	0
M5,M3	0	-0.3	-0.3	0.3	0.6
M5,M4	-0.3	0	-0.3	0	0.3
M5,M6	-0.3	-0.3	-0.3	0.3	0.6
M6,M1	0.3	0.6	0.3	-0.3	-0.6
M6,M2	-0.3	0.6	0.6	-0.6	-0.6
M6,M3	0.3	0	0	0	0
M6,M4	0	0.3	0	-0.3	-0.3
M6,M5	0.3	0.3	0.3	-0.3	-0.6

The preference function values are computed as mentioned in the methodology and they are represented in Table.11.

Table.11. Preference Function Values

M1,M2	-0.138	**M2,M1**	0.138	**M3,M1**	0.03
M1,M3	-0.03	**M2,M3**	0.108	**M3,M2**	-0.108
M1,M4	-0.144	**M2,M4**	-0.006	**M3,M4**	-0.114
M1,M5	-0.069	**M2,M5**	0.069	**M3,M5**	-0.039
M1,M6	-0.102	**M2,M6**	0.036	**M3,M6**	-0.072
M4,M1	0.144	**M5,M1**	0.069	**M6,M1**	0.102
M4,M2	0.006	**M5,M2**	-0.069	**M6,M2**	-0.036
M4,M3	0.114	**M5,M3**	0.039	**M6,M3**	0.072
M4,M5	0.075	**M5,M4**	-0.075	**M6,M4**	-0.042
M4,M6	0.042	**M5,M6**	-0.033	**M6,M5**	0.033

The positive and the negative flows are presented in Table 12.

Table 12. Positive & Negative outranking flows.

Φ^+ (M1) = -0.483	Φ^- (M1) = 0.483	**Φ (M1) = -0.966**

Φ^+ (M2) = 0.345	Φ^- (M2) = -0.345	**Φ (M2) = 0.69**
Φ^+ (M3) = -0.303	Φ^- (M3) = 0.303	**Φ(M3) = -0.606**
Φ^+ (M4) = 0.381	Φ^- (M4) = -0.381	**Φ (M4) = 0.762**
Φ^+ (M5) = -0.069	Φ^- (M5) = 0.069	**Φ (M5) = -0.138**
Φ^+ (M6) = 0.129	Φ^- (M6) = -0.129	**Φ (M6) = 0.258**

4. Results and Discussion

The values of the third column of Table 12 represent the difference between positive and negative outranking flows. It is very evident that M4 → M2 →M6 →M5 →M3 →M1. This implies the method recycling ranks as the most feasible methods of industrial waste management followed by composting, bio gas technology, incineration, landfill and segregation. The recycling method satisfies the criteria of a waste management method and it suits the economic and environmental needs of the industries.

Conclusion

This paper introduces a new approach of Octa-Hexa fuzzy PROMTHEE decision making model which makes use of octagonal and hexagonal fuzzy numbers for linguistic variable representation. This approach is more realistic and it enables the decision makers to contribute their preference in a comprehensive manner. The results obtained will duly assist the industrialist in adopting the waste management method fulfilling their needs. This work can be extended by using other combination of higher order fuzzy numbers.

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