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Application of Promethee with Fuzzy Criteria on Daily Life Problems

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Abstract—*This paper proposes the application of PROMETHEE outranking multi-criteria decision making technique with fuzzy criteria on some daily life multi-criteria problems. In many situations, selection of particular alternatives based on certain are found out to be very difficult in our daily life. This paper shows that such problems can easily be solved by such benchmark multi-criteria decision making technique. Two real life case studies have been depicted and PROMETHEE has been applied on them and the numerical results are shown.*

Keywords*: Fuzzy probability, Triangular Fuzzy Number, TOPSIS, Multi-Criteria Decision Analysis technique.*

1. INTRODUCTION

Decision making in practical problem generally consists of multiple criteria. Thus the existing literature shows significant number of Multi-Criteria Decision Analysis (MCDA) techniques in order to solve such problems. A few of such techniques include Analytical Hierarchy Process (AHP), TOPSIS, PROMETHEE, MACBETH, ANP and so on [1]. These techniques have been applied in numerical applications. Some of those research studies the works of Bandyopadhyay and Bhattacharya [2], Kumar et al. [3], Ho et al. [4], Galankashi et al. [5], Lima et al. [6], Shemshadi et al. [7] and so on. Besides, there are hybrid methods as proposed in the literature. for example, Bilişik et al. [8] combined weighted satisfaction score with correlation coefficient; Feng et al. [9] combined multi-objective programming model ad Tabu search algorithm; Scott et al. [10] combined AHP with Quality Function Deployment; Rezaei and Davoodi [11] combined Integer Programming with Genetic Algorithm; Zeydan et al. [12] combined fuzzy AHP with fuzzy TOPSIS. In spite of such vast number of applications, there are still numerous aspects of MCDA techniques which need attention from the researchers and practitioners of the respective fields of study. Some of those aspects include the need of a method to compare the results of MCDA techniques, accounting for the cases where the consideration of alternatives and/or criteria is uncertain and so on. This paper addresses the problem of a real life MCDA problem with fuzzy criteria. PROMETHEE multi-criteria technique has been applied for the purpose. The technique applied in this paper is briefly described through numerical example. The book of Ishizaka and Nemery [1] can be consulted for the concept of the basic PROMETHEE.

2. PROMETHEE MCDA TECHNIQUE

The PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations) Multiple Criteria Decision Analysis (MCDA) technique is depicted in brief in this section. The inputs to this technique are set of alternatives (A_i), set of criteria (C_j), set of decision makers (or situations), linguistic terms for criteria, preferences from decision makers for criteria. The output is the ranking of the alternatives. The steps of this technique are shown below.

Step 1: Linguistic values of the fuzzy criteria are translated to the respective triangular fuzzy numbers.

Step 2: The preference function values are calculated next. Let the values of the alternatives A1 and A2 for criterion C_1 are X_1 and X_2. Thus the preference function value for the pair of alternatives (A1, A2) is: $X_1 - X_2$

Step 3: Preference index values are calculated from the preference function values by multiplying the preference function values for each criterion with the corresponding weight of the criterion and then summing up the resulting values as: $X_1 \times W_1 + X_2 \times W_2 + ...$

Step 4: Now the positive and negative outranking flows are calculated by the expressions (1) and (2) respectively.

$$\phi^{+}(A_i) = \frac{1}{n} \sum_{j=1, j \neq i}^{m} (A_i, A_j) \quad (1)$$

$$\phi^{-}(A_i) = \frac{1}{n} \sum_{j=1, j \neq i}^{m} (A_j, A_i) \quad (2)$$

Where, m is the number of alternatives and $n = m - 1$, excluding the alternative whose outranking flow is being found out.

The fuzzy final outranking flow is calculated by expression (3).

$$\phi(A_i) = \phi^+(A_i) - \phi^-(A_i)$$

Greater the value of the final outranking flow for an alternative, greater is its rank. Thus the highest ranked alternative has the highest value for the final outranking flow.

3. APPLICATION OF PROMETHEE

The following cases have been used for this study.

Case I: Anil lives in Baguiati and just recently got chance in M.Tech. Study in Jadavpur University (JU). Thus he will have to go to JU every day and will have to reach JU by 10:30 AM in the morning. Anil has some monthly income based on the coaching center that he runs in his owns home during Sundays. Besides, he also earns through private tuition in two other places during evening time. Thus he will have to spend very cautiously for conveyance from Baguiati to Jadavpur. Since he will have to study after returning home in the evening, he will have to restore his energy. Besides, because of health conditions at different times, variations in cash availability, time requirements at his department, he has different preferences of criteria at different times. A total of four such situations, each with different set of preferences is considered. While choosing an alternative journey, he will have to minimize journey expenditure, minimize time, and maximize comfort level. He has the following alternative options for the daily journey, as shown in Table 1. The preferences are recorded as fuzzy criteria values (Table 2) whose linguistioc terms are explained in Table 3.

Table 1: Alternative Options for Case I

Alternative journey options	Monthly expenditure	Time required for to-and-fro journey	Comfort level with corresponding values
Direct Bus numbered 45 (A1)	Rs. 600	4 hours	Medium - 30
Direct Minibus (A2)	Rs. 900	3 hours	Medium -30
Bus to Shovabazar Metro, then Metro Rail, followed by Auto; return journey in the reverse way (A3)	Rs. 1500	3.5 hours	Low - 20
Bus to Sealdah, train to Jadavpur, then 10 minutes on foot; return journey in the reverse way (A4)	Rs. 350	2 hours 40 minutes	Very low – 10
AC bus running through Bypass (A5)	Rs. 2400	2 hours 20 minutes	Very high - 50
Direct Bus M2 running through Bypass (A6)	Rs. 750	2 hours 30 mites	High - 40

Table 2: Preferences of Decision Makers for Criteria for Case I

	C1	C2	C3
Situation 1	AI	I	AI
Situation 2	VI	AI	I
Situation 3	AI	VLI	I
Situation 4	VI	AI	VI

Table 3: Linguistic Terms for Criteria

Linguistic Terms	Triangular Fuzzy Number (TFN)
Very little important (VLI)	(0.0, 0.0, 0.20)
Less important (LI)	(0.0, 0.20, 0.40)
Important (I)	(0.20, 0.40, 0.60)
Very important (VI)	(0.40, 0.60, 0.80)
Absolute importance (AI)	(0.60, 0.80, 1.00)

PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations) is now applied on the above problem. the parameters for this case is shown in Table 4.

Table 4: Parameters for Case I

Total number of Alternatives	6	
Total number of Decision Makers (DMs)	4	
Total number of Criteria	3	
Criteria as considered in this paper	C1	Monthly Expenditure (E)
	C2	Time required for to-and-fro journey (T)
	C3	Comfort level (C)

At first, the linguistic values as shown in Table 2 are expressed through the triangular fuzzy numbers as shown in Table 3. Then the simple averages are calculated and the mean representations of these resultant values are calculated as shown in Table 5. The mean representations represent the weights of the criteria.

Table 5: Weights of Fuzzy Criteria for Case I

Criteria	Triangular Fuzzy Weights	Mean Representation
C1	(0.5, 0.7, 0.9)	0.35
C2	(0.35, 0.5, 0.7)	0.5375
C3	(0.35, 0.55, 0.75)	0.7375

Next, the values of the alternatives as shown in Table 1 are modified to some extent by dividing the values of monthly expenditure by 100 and are given in Table 6.

Table 6: Modified Values for the Alternatives against Each Criterion

	C1	C2	C3
A1	6	24	30
A2	9	18	30

A3	15	21	20
A4	35	16	10
A5	24	14	50
A6	75	15	40

Based on Table 6, the preference function values are calculated following the expression as depicted in Section 2 and are shown in Table 7. For example, the values for criteria for alternatives A1 and A2 are 6,24,30 and 9,18,30 respectively. Therefore, the values in the first row of Table 7 are calculated as: $6-9, 24-18, 30-30 = -3, 6, 0$.

Table 7: Preference Function Values for Case I

A1,A2	-3	6	0
A1,A3	-5	13	19
A1,A4	-6	12	18
A1,A5	-18	10	-20
A1,A6	-69	9	-10
A2,A1	3	-6	0
A2,A3	-6	-3	10
A2,A4	-26	2	20
A2,A5	-15	4	-20
A2,A6	-66	3	-10
A3,A1	9	-3	-10
A3,A2	6	3	-10
A3,A4	-20	5	10
A3,A5	-9	7	-30
A3,A6	-60	6	-20
A4,A1	29	-8	-20
A4,A2	26	-2	-20
A4,A3	20	-5	-10
A4,A5	11	2	-40
A4,A6	-40	1	-30
A5,A1	18	-10	20
A5,A2	15	-4	20
A5,A3	9	-7	30
A5,A4	-11	-2	40
A5,A6	-51	-1	10
A6,A1	69	-9	10
A6,A2	66	-3	10
A6,A3	60	-6	20
A6,A4	40	-1	30
A6,A5	51	1	-10

After this, the preference index values, positive outranking flows, negative outranking flows and the net outranking flow for each alternative are shown in Fig. 1. Preference index for any pair of alternatives is calculated by multiplying the preference function values with the corresponding criterion value and then summing the resulting values. For example, the preference function values for the pair of alternatives (A1, A2) for criteria C1, C2 and C3 are -3, 6, 0 respectively. These values are multiplied with the weights of criteria (0.35, 0.5375, 0.7375) (see Table 5). The resulting values are: $-3\times0.35+6\times0.5375+0\times0.7375=2.3$.

Preference Index Values

A1,A2	2.3
A1,A3	20.46667
A1,A4	18.7
A1,A5	-17.0333
A1,A6	-30.1833
A2,A1	-2.3
A2,A3	3.683333
A2,A4	6.433333
A2,A5	-19.3333
A2,A6	-32.4833
A3,A1	-5.98333
A3,A2	-3.68333
A3,A4	2.75
A3,A5	-23.0167
A3,A6	-36.1667
A4,A1	-8.73333
A4,A2	-6.43333
A4,A3	-2.75
A4,A5	-25.7667
A4,A6	-38.9167
A5,A1	17.03333
A5,A2	19.33333
A5,A3	23.01667
A5,A4	25.76667
A5,A6	-13.15
A6,A1	30.18333
A6,A2	32.48333
A6,A3	36.16667
A6,A4	38.91667
A6,A5	13.15

Outranking Flows

	ϕ^+	ϕ^-	ϕ	RANK
A1	-1.15	6.04	-7.19	3
A2	-8.8	8.8	-17.6	4
A3	-13.22	16.11667	-29.3367	5
A4	-16.52	18.51333	-35.0333	6
A5	14.4	-14.4	28.8	2
A6	30.18	-30.18	60.36	1

Fig. 1: Preference Index Values and Outranking Flows

Fig. 1 shows that the highest ranked alternative is alternative A6, that is, “Direct bus M2 running through Bypass”.

CASE II: Rina presents two Sarees to her mother on the occasion of yearly festival every year. Rina income level is not high enough to purchase expensive Sarees during the festival time because of many other expenses during the festival time. Thus she decides to purchase the Sarees well before the festival approaches. Her target is to minimize cost, maximize quality of the Sarees, minimize journey effort and minimize time. Thus she has the following alternatives as shown in the table below.

Table 8: Alternative Options for Case II

Alternatives	**Cost**	**Quality**	**Journey effort**	**Time required for marketing**
Nearby local market (A1)	Rs. 11300	Acceptable 1	Moderate - 30	2 hours 30 minutes = 150
Online purchase (A2)	Rs. 3800	High – 3	Very low - 10	10 minutes
Gariahat Market (A3)	Rs. 8000	High - 3	Very high - 50	4 hours = 240
Hati Bagan Market (A4)	Rs. 8500	Medium 2	Moderate - 30	3 hours = 180

The respective preference values for various situations are shown in Table 9.

Table 9: Preferences of Decision Makers for Criteria

	C1	**C2**	**C3**	**C4**
Situation 1	VI	VI	AI	LI
Situation 2	AI	AI	VI	LI
Situation 3	AI	VLI	I	AI
Situation 4	VI	AI	LI	I

The respective other set of values for Case II are shown in Fig. 2 below. The highest ranked alternative is alternative A3, that is, “Gariahat Market”.

Aggregated Triangular Fuzzy Weights for Criteria

Criteria	Triangular Fuzzy Weights	Mean Representation
C1	(0.5, 0.7, 0.9)	0.35
C2	(0.4, 0.55, 0.75)	0.5375
C3	(0.3, 0.5, 0.7)	0.7375
C4	(0.2, 0.4, 0.6)	0.225

Preference Index Values

A1,A2	61.75
A1,A3	-34.2
A1,A4	-2.325
A2,A1	-61.75
A2,A3	-95.95
A2,A4	-64.075
A3,A1	34.2
A3,A2	95.95
A3,A4	31.875
A4,A1	2.325
A4,A2	64.075
A4,A3	-31.875

Modified Values for the Alternatives against Each Criteria

	C	Q	J	T
A1	11300	10	30	150
A2	3800	30	10	10
A3	8000	30	50	240
A4	8500	20	30	180

Preference Function Values

	C1	C1′	C2	C3	C4
A1,A2	7500	75	-20	20	140
A1,A3	3300	33	-20	-20	-90
A1,A4	2800	28	-10	0	-30
A2,A1	-7500	-75	20	-20	-140
A2,A3	-4200	-42	0	-40	-230
A2,A4	-4700	-47	10	-20	-170
A3,A1	-3300	-33	20	20	90
A3,A2	4200	42	0	40	230
A3,A4	-500	-5	10	20	60
A4,A1	-2800	-28	10	0	30
A4,A2	4700	47	-10	20	170
A4,A3	500	5	-10	-20	-60

Outranking Flows and Rank of Alternatives

	ϕ^+	ϕ^-	ϕ	RANK
A1	8.408333	-8.40833	16.81667	3
A2	-73.925	73.925	-147.85	4
A3	54.00833	-54.0083	108.0167	1
A4	11.50833	-11.5083	23.01667	2

Fig. 2: Weight of Criteria, Preference Function and Preference Index Values and Outranking Flows

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