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APPLYING FUZZY PROMETHEE MULTI-CRITERIA TECHNIQUE FOR SUPPLIER RANKING PROBLEM

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Abstract— This paper applies fuzzy PROMETHEE outranking Multi-Criteria Decision Analysis Method to solve Supplier ranking problem. The triangular fuzzy concept is applied in order to find the weights of the criteria on the basis of which the suppliers are ranked. In this paper, a total of five criteria have been considered to rank the suppliers. These criteria are – 1) experience of the suppliers, 2) quality of the products, 3) delay in delivering the products, 4) the prices of the products and 5) miscellaneous costs. Based on the data on these criteria on each of these suppliers, the preference values and index are first calculated for pair-wise comparison and finally the outranking flows are calculated which indicates the final rankings of the suppliers.

Keywords— Outranking Methods; PROMETHEE; Fuzzy; Supplier ranking

I. INTRODUCTION

In Multi-Criteria Decision Analysis (MCDA) techniques, a set of values for various criteria for a problem are generally provided based on which any one alternative from a set of alternatives is chosen. There are a large number of MCDA techniques as seen in the existing literature. Some of these techniques are: SMART (Simple Multi-Attribute Rating Technique), Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Aggregated Indices Randomization Method (AIRM), Data Envelop Analysis (DEA), Dominance-based Rough Set Approach (DRSA), Elimination and Choice Translating Reality (ELECTRE), Evidence Reasoning (ER) approach, PROMETHEE and so on. The PROMETHEE as applied in this research study takes two inputs – 1) preference values from the decision makers and 2) the data values of the criteria as returned from the agents. In this research study, a total of five criteria have been assumed for ranking a set of suppliers. PROMETHEE is suitable for multi-criteria problem of the type given as $\max imize/\min imize\ \{f_1(a), f_2(a),..., f_n(a)\}\,|\,a \in A\}$. The following subsection gives a brief overview of PROMETHEE.

A. PROMETHEE Multi-Criteria Technique

MCDA techniques can be categorized into: 1) Value Measurement Models, 2) Goal, Aspiration and Reference Level Models and 3) Outranking models. Outranking is a binary relation *S* defined in set *A* such that *aSb* if, given the information relating to the decision maker's preferences, there are enough arguments to decide that' 'a is at least as good as b'' while there is no reason to refute this statement. Examples of such techniques include - ELECTRE I, II, III, IV; PROMETHEE; NAIADE. This paper applies PROMETHEE outranking method to rank a set of suppliers.

The PROMETHEE as applied in this research study takes two inputs – 1) preference values from the decision makers and 2) the data values of the criteria as returned from the agents. In this research study, a total of seven criteria have been assumed for routing of a job to the next optimum neighbor towards destination. PROMETHEE is suitable for multi-criteria problem of the type given below.

$$\max imize/\min imize\ \{f_1(a), f_2(a),..., f_n(a)\}\,|\,a \in A\} \qquad (1)$$

Where, *A* is the set of alternatives, f_j denotes the *j-th* criterion to be maximized or minimized. $f_j(a)$ is the evaluation of an alternative *a* for the *j-th* criterion.

In PROMETHEE as applied in this research study, at first, each decision maker assigns preference values to the criteria. Thus if there are *m* decision makers and *C* number of criteria, then we get a $m \times C$ preference matrix with preference values from the decision makers. From this matrix, a matrix of the same order $m \times C$ is formed which contains all normalized values as calculated from the preference values by expression (2).

$$v_{ij} = \frac{\Pr_{ij}}{\sum_{j=1}^{C} \Pr_{ij}} \qquad (2)$$

Where, v_{ij} is the normalized value of the preference and an entry in the *i-th* row and *j-th* column in the matrix containing normalized values for the *i-th* decision maker and the *j-th* criterion; $\Pr_{ij}$ is the respective original preference value delivered by *i-th* decision maker, for the *j-th* criterion.

Next, the minimum ($\min_j$), maximum ($\max_j$) and an intermediate (avg_j) values are found out of the *m* normalized preference values for each of the *C* criteria and the weight for the *j*-th criterion is calculated by expression (3).

$$W_j = (\min_j + avg_j + \max_j)/3 \qquad (3)$$

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The preference function for comparing the alternatives in this research study is calculated by expression (4).

$$P_j(a,b) = -[f_j(a) - f_j(b)] \quad (4)$$

Where, *a* and *b* are two alternatives. After calculating the preference function, the preference index is calculated for each pair of alternatives by expressions (5) and (6).

$$\pi(a,b) = \sum_{j=1}^{C} W_j P_j(a,b) \quad (5)$$

$$\pi(b,a) = \sum_{j=1}^{C} W_j P_j(b,a) \quad (6)$$

Then the outranking flows are calculated by expressions (7) and (8).

$$\phi^+(a) = \frac{1}{(n-1)} \sum_{x \in A} \pi(a,x) \quad (7)$$

$$\phi^-(a) = \frac{1}{(n-1)} \sum_{x \in A} \pi(x,a) \quad (8)$$

Expressions (7) and (8) are called the positive and negative outranking flows respectively. The PROMETHEE II complete ranking is finally calculated from expression (9) as provided below.

$$\phi(a) = \phi^+(a) - \phi^-(a) \quad (9)$$

The higher the value of $\phi(a)$, greater is the rank of an alternative *a*. This is the rule for ranking the alternatives.

II. LITERATURE REVIEW

Numerous applications of popular PROMETHEE and other MCDA methods are observed in the existing literature. Some of these are described in this section, in brief. Lin et al. [1] applied both AHP and PROMETHEE for offshore outsourcing decisions. AHP had been used for the selection of location whereas PROMETHEE had been used for final ranking of those selected locations. Gupta et al. [2] applied AHP for asset allocation problem. The method used for the purpose is actually a hybrid process which combined behavior survey and cluster analysis with AHP. Liao and Kao [3] also used a hybrid method, combining AHP with Taguchi loss function and Goal Programming methods. The application area of the hybrid method was supplier selection problem. Sharma and Dubey [4] applied AHP on Knapsack problem. Some of the other significant research studies on AHP include the research studies of Önüt et al. [5], Majumdar [6], Azadeh et al. [7].

Kodikara et al. [8] applied PROMETHEE to evaluate the alternative operating rules for urban water supply problem. The major stakeholders considered in this paper were resource managers, water users and environmental interest groups. Wang and Yang [9] used both AHP and PROMETHEE for information system outsourcing decisions. The criteria considered for decision making were economics, resource, strategy, risk, management and quality. The weights of the criteria and the problem structure were determined by AHP and the final ranking of the alternatives was performed by PROMETHEE. Lin et al. [10] used both AHP and PROMETHEE in offshore outsourcing location selection problem. Following the usual practice, AHP had been used to decide over the structure of the problem and calculating the weights of the criteria considered and PROMETHEE was used to the final ranking of the alternatives. Some of the other significant research studies on PROMETHEE include the research studies of Mergias et al. [11], Tuzkaya et al. [12]. This paper applies fuzzy PROMETHEE to rank a set of suppliers. The following section shows the application of PROMETHEE by a numerical example.

III. NUMERICAL EXAMPLE

The fuzzy PROMETHEE has been applied to a suppliers' ranking problem. The calculations have been dome by basic C++ programming in a PC with 2.8 GHz Processor and 4 GB memory.

The data as obtained about 10 suppliers are shown in Table 1. Table 2 shows the preference values as assigned by 6 decision makers.

Table 1. Suppliers' Data

Supp -lier	Supplier experience	Quality of product	Delays (days)	Product price	Misc. costs
1	8	5	10	730	132
2	6	6	12	750	134
3	5	6	16	600	159
4	12	7	14	640	120
5	3	8	15	720	170
6	12	9	18	500	140
7	14	8	10	660	135
8	5	7	11	600	184
9	2	8	13	640	157
10	2	5	16	625	122

Table 2: Preference Values from Decision Makers

Decision maker	criteria				
	Supplier experience	Quality of product	Delays (days)	Product price	Misc. costs
1	5	1	4	2	3
2	5	2	1	3	4
3	1	4	2	3	5
4	4	3	5	1	2
5	4	1	3	2	5
6	3	5	4	1	2

From the preference values delivered by the decision makers, the normalized values of the preference values are calculated first following equation (2), followed by the calculation of fuzzy weights following equation (3) as shown in Figure 1.

Decision Maker	Criteria				
	Supplier's experience	Quality of product	Delays (days)	Product price	Energy cost
1	0.3333	0.0667	0.2667	0.1333	0.2
2	0.3333	0.1333	0.0667	0.2	0.2667
3	0.0667	0.2667	0.1333	0.2	0.3333
4	0.2667	0.2	0.3333	0.0667	0.1333
5	0.2667	0.0667	0.2	0.1333	0.3333
6	0.2	0.3333	0.2667	0.0667	0.1333
Maximum	0.3333	0.3333	0.2667	0.2	0.3333
Minimum	0.0667	0.0667	0.0667	0.0667	0.1333
Average	0.2	0.2	0.1333	0.1333	0.2
Graded Mean	0.2	0.2	0.1556	0.1333	0.2222

Fig.1. Calculation of Weights of Criteria

Then the preference function values are calculated following equation (4). The upper portion of Figure 2 shows the examples of some preference function values. From these values, preference index values are calculated following

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equations (5) and (6), as shown in the lower portion of Figure 2.

Pair of Alternatives	Supplier's experience	Quality of product	Delays (days)	Product price	Energy cost
S1, S2	-2	1	2	20	2
S1, S3	-3	1	6	-130	27
S1, S4	4	2	4	-90	-12
S1, S5	-5	3	5	-10	38
S1, S6	4	4	8	-230	8
S1, S7	6	3	0	-70	3
S1, S8	-3	2	1	-130	52
S1, S9	-6	3	3	-90	25
S1, S10	-6	0	6	-105	-10

EXAMPLES OF PREFERENCE FUNCTION VALUES

Pair of Alternatives	Preference Index	Pair of Alternatives	Preference Index	Pair of Alternatives	Preference Index	Pair of Alternatives	Preference Index
S1,S2	3.2216	S2,S1	-3.2216	S3,S1	10.796	S4,S1	12.841
S1,S3	-10.796	S2,S3	-14.0176	S3,S2	14.0176	S4,S2	16.0626
S1,S4	-12.841	S2,S4	-16.0626	S3,S4	-2.045	S4,S3	2.045
S1,S5	7.4886	S2,S5	4.267	S3,S5	18.2846	S4,S5	20.3296
S1,S6	-26.0366	S2,S6	-29.2582	S3,S6	-15.2406	S4,S6	-13.1956
S1,S7	-6.8644	S2,S7	-10.086	S3,S7	3.9316	S4,S7	5.9766
S1,S8	-5.819	S2,S8	-9.0404	S3,S8	4.977	S4,S8	7.022
S1,S9	-6.5752	S2,S9	-9.7968	S3,S9	4.2208	S4,S9	6.2658
S1,S10	-16.4849	S2,S10	-19.7065	S3,S10	-5.6889	S4,S10	-3.6439

EXAMPLES OF PREFERENCE INDEX VALUES

Fig. 2. Values of Preference Function and Preference Index

Finally the outranking flows are calculated following equations (7), (8) and (9), as shown in Figure 3. The third column of values of Figure 3 shows the final values which leads to the ranking of the suppliers. The higher the value, the higher is the rank of a supplier. Therefore the ranks of the suppliers for this example in descending order of ranks is: A6→A10→A4→A3→A7→A9→A8→A1→A2→A5, with the supplier number 6 securing the highest rank and supplier number 5 secures the lowest rank.

$\phi^+(S1) = -8.3008$	$\phi^-(S1) = 10.1771$	$\phi(S1) = -18.4779$
$\phi^+(S2) = -11.8803$	$\phi^-(S2) = 13.6579$	$\phi(S2) = -25.5382$
$\phi^+(S3) = 3.6948$	$\phi^-(S3) = -3.1516$	$\phi(S3) = 6.8464$
$\phi^+(S4) = 5.9670$	$\phi^-(S4) = -5.9670$	$\phi(S4) = 11.934$
$\phi^+(S5) = -11.3232$	$\phi^-(S5) = 14.2513$	$\phi(S5) = -25.5745$
$\phi^+(S6) = 20.6288$	$\phi^-(S6) = -20.6288$	$\phi(S6) = 41.2576$
$\phi^+(S7) = -0.6737$	$\phi^-(S7) = 0.6737$	$\phi(S7) = -1.3474$
$\phi^+(S8) = -1.6672$	$\phi^-(S8) = 1.8352$	$\phi(S8) = -3.5024$
$\phi^+(S9) = -0.9456$	$\phi^-(S9) = 1.1630$	$\phi(S9) = -2.1086$

OUTRANKING FLOWS

Fig. 3. Ranking the Suppliers Based on Outranking Flows

IV. CONCLUSION

This paper has applied fuzzy PROMETHEE outranking Multi-Criteria Decision Analysis technique in order to rank a set of suppliers. A total of 6 decision makers have been considered and fuzzy weights of the criteria have been calculated by graded mean average formula, based on the preference values as delivered by the suppliers. Numerical example has been provided and explained in order to explain the application of PROMETHEE to rank the suppliers based on some criteria.

Thus the main contribution of this lies in applying the fuzzy PROMETHEE in supplier ranking problem and the numerical example shows that such method is applicable for such problems. As a future research thought, a classification mechanism has been framed by some modified fuzzy versions of various outranking methods. The results of those experimentations will be compared to make valuable conclusions.

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