

Multi-Criteria Decision Making and its Applications

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Abstract: Multi-criteria decision making (MCDM) is a powerful operational model which are used to resolve decision making problems on the basis of different decision criteria. This approach has been widely used in many application fields by the decision makers to solve their problems. Although there exists different MCDM methods but the basic principle of MCDM method involves selection of criteria, selection of alternatives, selection of aggregation methods and weight criteria using these methods and finally evaluation of a set of alternatives performed based on criteria weights. This study presents a small description on the working principle and different methods of a Multi-criteria decision making and furthermore provides survey on their application in different fields.

Index Terms: Alternatives, Criteria, Multi-criteria decision making (MCDM), TOPSIS.

I. INTRODUCTION

Multi criteria decision making becomes an important operational research part, which supports the decision makers with structuring and resolving decision making problems. Multi criteria decision making (MCDM) is an approach of selecting the perfect alternative among all the possible alternatives on the basis of different decision criteria (Işıklar et al. 2007). MCDM process works on the common principle which are

- Selection of the criteria which should be coherent with the decision and independent of each other.
- Selection of the alternatives which should be available and comparable.
- Selection of the Weighing and Aggregation methods.

Decision making based on the Aggregated results.

II. MCDM METHODS CLASSIFICATION

There are many ways using which MCDM methods can be classified. One way of classification is based on the number of the decision makers i.e. single decision making and group decision making methods. MCDM methods can also be distinguished according to the information used and feature of this information (Chen and Hwang, 1992). Some of the most commonly used method are discussed here.

The weighted sum model (or WSM) is the commonly used simple MCDM method, especially for single dimensional problems. The best alternative from M alternatives and N criteria can be evaluated using following equation (Fishburn,1971)

$$A wsm_i = Max \sum_{j=1}^n w_j a_{ij} \quad (1)$$

The weight product model (or WPM) is analogues to the weighted sum model but the only difference is that the best alternative can be evaluated by comparing the ratio of the corresponding criterion using the following equation (Bridgman,1922 and Triantaphyllou,2000).

$$P(A_k/A_i) = \prod_{j=1}^n (a_{kj}/a_{ij})^{w_j} \quad (1)$$

The Elimination and Choice Translating Reality (ELECTRE) method was developed by Bernard Roy,1991 at SEMA company. This method uses the working principle of outranking approach and creates the pairwise comparison matrix among the alternatives corresponding to each criterion and make the “outranking relations” using these matrices. The outranking relationship of A_i with A_j describes the event when the i^{th} alternative does not perform better than the j^{th} alternative quantitatively, then the decision maker may ignore A_j and can consider A_i as better than A_j . Finally, it produces the leading alternatives after eliminating the less favorable alternatives. A Preference Ranking Organisation Method (PROMETHEE) is another MCDM technique which uses the concept of outranking approach (Brans & Vincke,1985).

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), developed by Hwang and Yoon, is an alternative decision-making method of ELECTRE method. The basic concept used by this method is that the feasible selected alternative possesses the minimum distance from the ideal solution and the maximum distance from the negative-ideal solution. This method usually makes an assumption that each criterion has monotonically increasing or decreasing tendency, which becomes easy to locate the positive or negative ideal solutions (Hwang & Yoon,1981). The Euclidean distance method is then used to measure the distances of each alternative which sets the preference order for each alternative.

The Analytical Hierarchy Process (AHP) is an another MCDM method which was developed by Saaty and this method decomposes complex problem into small hierarchies of attributes and alternatives. AHP mainly uses the concept of the priority-based theory.

The relative priority or weight of alternatives with respect to the criterion is evaluated in the form of M X N matrix. This method works with relative values rather than actual values; hence it is used in the single as well as multi-dimensional decision problems. Fuzzy AHP is an advanced version

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of AHP model, which uses the concept of fuzzy theory along with hierarchal structure analysis to solve decision making problem. Initially the fuzzy numbers with triangular membership functions was used to describe the fuzzy comparing judgment (Van Laarhoven and Pedrycz, 1983) but later on the fuzzy priorities of comparison ratios with trapezoidal membership functions was used. Chang (1996) proposed a new method which works using the extent analysis method for the pairwise comparison scale of AHP and the synthetic extent values of the pairwise comparisons, respectively along with the triangular fuzzy numbers.

			becomes clear.	
6.	Fuzzy Analytic hierarchy process (FAHP)	It also includes pairwise comparison of different alternatives for different criterion using fuzzy numbers.	1. Since fuzzy numbers are used it reduces uncertainty. 2. Less bias in decision making	Slow while solving large or complex problems.

TABLE I. MULTI-CRITERIA DECISION MAKING METHODS AND ITS MERITS AND DEMERITS

No.	MCDM Methods	Description	Advantages	Disadvantages
1.	Weighted Sum Model (WSM)	It is used for evaluating a number of alternatives in accordance to the different criteria which are expressed in the same unit.	Strong in a single dimensional problem	Less flexible with multi-dimensional problems
2.	Weighted Product model (WPM)	Alternatives are being compared with the other by the weights and ratio of one for each criterion.	Relative values are used rather than actual ones.	No solution for DMs with equal weight
3.	ELECTRE/PROMET/HEE	It is used to select the more favourable and less conflict alternative in various criteria	Outranking is used	Time consuming
4.	TOPSIS	It aggregates and represents decision close to an ideal solution.	Gives best optimal solution.	Less flexible
5.	Analytic hierarchy process (AHP)	It also includes pairwise comparison of different alternatives for different criterion.	1. Flexible and intuitive 2. Since problem is constructed into a hierarchical structure, the importance of each element	1. Irregularities in ranking 2. More number of pairwise comparisons are needed

III. APPLICATIONS

MCDM methods are found applicable in evaluating and managing the real-world problems in various sectors. Some of the MCDM methods applications are discussed in this section. In Industry, MCDM has number of applications which includes the decision analysis in manufacturing (Chakraborty et al., 2014), to resolve the decisions problems related to the technology investment (Boucher and McStravic, 1991). Fuzzy AHP is also used for industrial automation e.g. Development of fuzzy logic-based PLC's like Moeller which can be used to restrict or manage the industrial processes.

Fuzzy MCDM plays an important role in the banking applications, especially in the performance evaluation of bank (Tzeng & Chen, 2009), which can help creditors or investors to determine the bank's capabilities. Fuzzy TOPSIS method found useful to develop credit limit allocation model for different regions.

MCDM techniques combines with the GIS are useful in the landslide susceptibility mapping, evaluation of land use suitability and allocation (Pereira, 1993) and in the estimation of the proper placement of photovoltaic solar power plants (Uyan, 2013).

MCDM has a large number of applications related to the renewable energy issues i.e. in the planning and evaluation of renewable energy policy, project selection and allocation etc. (Taha & Daim, 2013).

In agriculture, Multi criteria decision analysis are useful in production analysis for irrigated farms, agricultural resource management and risks aversion. The MCDM technique along with Analytical network process developed a DEMATEL model that can be used to analyze the agricultural land suitability depending on the different criteria like temperature, wind, soil, water etc. (Pourkhabbaz et al., 2013). MCDM methods like TOPSIS, VIKOR, AHP along with fuzzy logic are found useful in the assessment of the performance of health care services (Karadayi et al., 2014). Some infectious waste is generated in healthcare facilities; it should be disposed in proper manner.

To select an optimal waste dispose firm from different alternatives, multi criteria decision making grey theory-based model was used (Thakur et al., 2015).

MCDM methods also plays an important role applicable in other fields i.e. in the Education sector for the evaluation of teacher's performance for appraisal, student's evaluation, in the selection of supervisor, to rank the Universities (Wu, H. Y. et al., 2012), in the Construction management for the investors, to analyze the construction risks, in the public office building for



selection of tenders related to designing and planning (P&D) (Hsieh et al., 2004), in the road and airline safety management and several other fields.

Sl. No	MCDM Technique	Application Area	Reference
1	ELECTRE	Selection of solid waste management system	Hokkanen et al 1995
2		Energy Planning	Beccali et al. 1998
3		Selection of route for Dublin port motorway	Rogers & Bruen,2000
4		Water supply system decision	Morais et al. 2006
5		Improving house design performance	Oltean-Dumbra va ,2006
6		Requirement prioritization	Mary et al. 2016
7	PROMETHEE	Evaluation of international banking sector	Mareschal & Mertens, 1992
8		Water resources planning	Abu-Taleb & Mareschal,1995
9		RANKING OF ALTERNATIVE ENERGY EXPLOITATION PROJECTS	Goumas & Lygerou,2000
10		Equipment selection	Dağdeviren,2008
11	TOPSIS	Inter-Company comparison	Deng et al.2000
12		Assessment building requirement analysis	Li et al. 2011
13		Ranking of General circulation models	Raju et al. 2015
14	Fuzzy TOPSIS	Company Plant location selection	Yong,2006
15		Supplier selection	Boran et al. 2009
16	Analytic hierarchy Process (AHP)	Supplier Selection	Nydick & Hill ,1992
17		Contractor Selection	Fong et al.,2000
18		Environment management plan	Ramanathan,2001
19		Project Management evaluation	Al-Harbi, 2001
20		Prioritize resource allocation	Cheng & Li ,2001
21		Selection of project delivery method	Mahdi & Alreshaid,2005
22		Evaluation of Information and Communication Technology (ICT) network system in health services	Oddershede et al. 2008
23		Selection of Solar site firms	Uyan,2013
24	Analytic hierarchy Process (AHP) with SWOT Analysis	Forest-certification	Kurttila et al.,2000

25	Fuzzy AHP	Modular product design	Lee et al. 2001
26		Program aspect assessment	Belton & Stewart, 2002.
27		Determine the optimum spatial allocation	Wu, Lee & Lin, 2004
28		Capital Investment	Tang et al., 2005
29		Operating system selection	Tolga et al. ,2005
30		Risk based environmental decision making	Tesfamariam & Sadiq,2006
31		Prioritization of strategies for reuse of treated waste water	Khoram et al. 2007
32		Assessment of water management plans	Srdjevic & Medeiros,2008
33		Evaluation of energy sources	Meixner,2009
34		Evaluation and selection of product of computers	Srichetta et al., 2012
35		Supplier selection problem	Ayhan ,2013
36		Plant Species Selection	Alavi,2014
37		Evaluating teaching performance	Chen et al. 2015
38		Ship energy efficiency management plan	Beşikçi et al. ,2016
39		Industrial site selection	Taibi & Atmani,2017
40		Measuring healthcare services	Singh & Prasher ,2019
41	MCDM	Software defect detection algorithms selection	Peng et al. 2010
42	Fuzzy AHP with Fuzzy TOPSIS	Water Loss Management	Zyoud et al.,2016
43	SAW, TOPSIS, Fuzzy TOPSIS	Cultivation priority planning for maize, rapeseed and soybean crops	Syedmohammadi et al.,2018

Initially, MCDM techniques ELECTRE, PROMETHEE, TOPSIS, AHP were used in different application areas like supplier selection, resources planning etc., now a day these techniques are embedded with Fuzzy sets to reduce the uncertainties in different application areas (Table 2). Instead of using single technique, combination of different (hybrid) techniques can be used for various applications which may produce better results.

IV. CONCLUSION

Many MCDM methods like AHP, TOPSIS, ELECTRE are available which are helpful to resolve



the decision-making problems. The basic concept of all the methods remains same, only the weight determination concept differs. These methods have different applications in different fields like Energy, GIS, Agriculture, Industry, Construction and other sectors. An appropriate approach has been selected according to the problem and its domain.

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