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Fuzzy multi criteria decision making and its applications: A brief review of category

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Abstract

Multi criteria decision making was introduced in the early seventies along side with the inception of fuzzy set theory. The theory has been fitted well with the decision making thereby innovates many novel methods of fuzzy multi criteria decision making. This paper presents a brief review of category in fuzzy multi criteria decision making and describes some of its earliest and recent applications. Several real life applications were presented to offer a glimpse of category in fuzzy multi criteria decision making and its applications.

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Keywords: fuzzy sets; decision making; uncertainty; multi criteria

1. Introduction

Decision making is becoming an important activity in the ultra-modern world despite being invaded with various updated technology advancements assisted decision tools. Technology alone sometimes fails to deliver a decision without considering human cognitive capability. Human equips with a good insight are expected to capitalize effective decision making to reach a very amicable decision. One of the promising decision making tools that was conceptualized in early seventies is multi criteria decision making theory. The theory of decision making formed a basis for more systematic and rational decision making especially in the situation where multiple criteria need to be accounted. This decision theory does not take so much time to fully recognized with the four terms consolidated to be known as multi criteria decision making (MCDM). The theory was further developed in line with the development of uncertainty and chaos theory. The uncertainty theory of fuzzy set theory which was introduced by Zadeh [1] has been overwhelmingly accepted by MCDM enthusiast. The fusion of MCDM and fuzzy set theory strengthen a new decision theory which was later being known as Fuzzy MCDM. Carlsson and Fuller [2] reinforced the role of fuzzy sets in decision making. Fuzzy MCDM methods have been found in many practical applications in the real word. However, the fusion has not comes without critics and pessimistic view. In 1984, French [3] predicted a very pessimistic future for fuzzy decision making. He once acknowledged the extension of fuzzy sets in decision making but later mulling in unpromising notes. The excerpt of French pessimistic remark is given as

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‘It is now some sixteen years since Zadeh awakened interest in the concept of fuzzy sets and over a decade since he and Bellman extended the analysis to decision making in a fuzzy environment. The intervening years have seen the development of a large and growing literature. Yet, despite the enormous amount of research into the theory and applications of fuzzy sets, there are still some fundamental questions to be answered. It is my contention that these cannot be resolved as favourably as the proponents of fuzzy mathematics suggest. Moreover, I argue that the emphasis placed upon the modelling of imprecision is inappropriate for many of the applications suggested to the theory’

Fortunately, nowadays we can see the light at the end of the tunnel. Everything developed exactly contrary to French's assessments. The last twenty five years have seen strong footing for future possibilities of fuzzy MCDM. However, to gain the positive outlook of fuzzy MCDM is a challenging task. Many researches in this area are still failing to be internalized and appreciated. Perhaps, negative notes such as no future perspectives continuously plague many scholars’ minds. The aims of this review paper are to revisit the uncertain membership of fuzzy sets and also to elucidate the categories of fuzzy MCDM. This paper also brings the latest experiences of real life application in Malaysia to illustrate the applications of Fuzzy MCDM in each category. This paper is structured as follows. Brief definition of fuzzy set theory is presented in Section 2. Section 3 describes the categories of fuzzy MCDM. Section 4 presents several examples of applications of fuzzy MCDM in Malaysia. This paper ends with a short conclusion in Section 5.

2. A Brief of Fuzzy Sets

In order to explain the concepts of fuzzy sets, the basic idea in classical set theory must be understood. In mathematics, the concept of classical set is very simple. A set is a collection of well-defined objects. These objects that cover almost anything can either belong in the set or not.

The classical set A in the universe $U, A \subset U$ is normally characterized by the function $\mu_A(x)$ which takes the value 1 or 0, indicating whether or not $x \in U$ is a member of A:

$$\mu_A(x) = \begin{cases} 1 & \text{for } x \in A \\ 0 & \text{for } x \notin A \end{cases}$$

Hence $\mu_A(x) \in \{0,1\}$ The function $\mu_A(x)$ takes only the values 1 or 0.

Now, assumed that the function $\mu_A(x)$ may take values in the interval [0, 1]. In this way the concept of membership is not crisp any more, but becomes fuzzy in the sense of representing partial belonging or degree of membership [4].

A fuzzy set R is defined by

$$R = \{(x, \mu_R(x)) / x \in A, \mu_R(x) \in [0,1]\}$$

where $\mu_R(x)$ is a function called the membership function; $\mu_R(x)$ specifies the grade or degree to which any element in A belongs to the fuzzy set R.

Ragin [5] had a very simple explanation about fuzzy sets. He iterated that the basic idea behind fuzzy sets is to permit the scaling of membership scores and this allows partial or fuzzy membership. A membership score of 1 indicates full membership in set; a score close to 1 (e.g., 0.8 or 0.9) indicates strong but partial membership in a set; scores less than 0.5 but greater than 0 (e.g., 0.2 and 0.3) indicate that objects are more “out” than “in” a set, but still weak members of the set; a score of 0 indicates full non membership of the set. Thus, fuzzy sets combine qualitative and quantitative assessment. The gradation of memberships in fuzzy sets provide vast opportunities to this theory to be seamlessly infiltrated in various knowledge domains including multi criteria decision making.

3. Category of Fuzzy MCDM

As MCDM developed to its maturity state, Carlson and Fuller [2] propose the categorization of MCDM into four major families. Outranking approach based on the pioneering work by Bernard Roy and implemented in the ELECTRE and PROMETHEE methods was categorized as the first. The second category is value and utility theory approaches. These approaches mainly started by Keeney and Raiffa and then implemented in a number of methods. Of these methods, a special and very well known method in this family is the Analytic Hierarchy Process (AHP) developed by Saaty and then implemented in the Expert Choice software package. The third category and the largest group is the interactive multiple objective programming (MOLP) approach with pioneering work done by Yu Stanley Zionts, Milan Zeleny, Ralph Steuer and a number of others. The fourth category of MCDM that classified by Carlsson and Fuller [2] is group decision and negotiation theory. This category introduced new ways to work explicitly with group dynamics and with differences in knowledge, value systems and objectives among group members. It seems that the fourth category is not well disseminated and perhaps indirectly diffused into one out of the first three categories.

Despite MCDM has been successfully applied in various knowledge domains, it still imperfectly matched with imprecise, vague and incomplete information. The flexibility, dynamic and receptive nature of MCDM opens a new multitude in leveraging the decision theory. When Bellman and Zadeh [6] and a few years later Zimmermann [7] introduced fuzzy sets into the playing field, it paves the way for a new category of decision methods to deal with problems which had been inaccessible and unsolvable with standard MCDM technique. When fuzzy set theory was introduced into MCDM research the methods were basically developed along the same lines. The first category of fuzzy MCDM contains a number of ways to find a ranking. This includes of degree of optimality, Hamming distance, comparison function, fuzzy mean and spread, proportion to the ideal, left and right scores, centroid index, area measurement, and linguistic ranking methods. The second category is built around methods which utilize various ways to assess the relative importance of multiple attributes and alternatives. Under this category, most of the methods were concentrated on weight determination. It comprises fuzzy simple additive weighting methods, fuzzy analytic hierarchy process, fuzzy conjunctive / disjunctive methods, fuzzy outranking methods and max-min methods. The third category and with the most frequent contributions is fuzzy mathematical programming. Flexible programming, possibilistic programming, possibilistic linear programming using fuzzy max, robust programming, possibilistic programming with fuzzy preference relations, possibilistic linear programming with fuzzy goals are among the popular methods under this category.

4. Applications

Since the emergence of fuzzy MCDM, there has been huge number of research which successfully tested in real life applications. This paper presents these applications into two parts. The first part presents among the earliest successful works of fuzzy MCDM. The second part presents among the most recent works executed by the author and colleagues.

4.1. Some Earliest Applications

One of the earliest practical applications of fuzzy MCDM was a commercial application for the evaluation of the credit-worthiness of credit card applicants. This was developed more than twenty years ago in Germany [6]. About a decade after the breakthrough in Germany, more and more real applications of fuzzy MCDM were reported. We briefly outline the three well known early day applications for the benefits of fuzzy MCDM enthusiast. Cheng and Mon [8] propose a new algorithm for evaluating weapon systems by the Analytical Hierarchy Process (AHP) based on fuzzy scales. There are two basic problems in weapon system evaluation: the objectives of the evaluations are generally multiple and in conflict and the descriptions of the weapon systems are usually linguistic and vague. The first problem can be solved by conventional MCDM techniques, but in order to tackle the second problem Cheng and Mon [8] propose the pressing need of fuzzy MCDM techniques. Cheng and Mon [8] derive a simple and general algorithm for fuzzy AHP by using triangular fuzzy numbers, alpha-cuts and interval arithmetic. Triangular fuzzy numbers scales from 1 to 9 were used to build a judgement matrix through pair-wise comparison techniques. They estimate the fuzzy eigenvectors of the judgement matrix by using an index of optimism to indicate the degree of satisfaction of the decision maker.

The application of fuzzy MCDM in biotechnology management is presented as second example. Chang and Chen [9] discuss the potential application of fuzzy MCDM techniques to the selection of technology transfer strategies in the area of biotechnology management. The transfer of technology from its source to the development of commercial applications is a very complex process. It is clearly a multi-person multi-criteria problem in an ill-structured situation. One should make a careful analysis among criteria, alternatives, weight, and decision makers before making a decision. If we want to use conventional crisp decision methods we will always have to find precise data. The assessments of alternatives on relation to various criteria, and the importance weights of these criteria have to rely on judgment or approximation. Linguistic variables and fuzzy numbers are used to aggregate the decision makers' subjective assessments of the weighting of criteria. Their method is based on using data input for computing the total index of optimism in a multi-person decision-making problem, instead of having a decision maker to give the index of optimism independently. This new approach used the index of optimism to rectify the pooled risk-bearing attitude of several decision makers. The index of optimism is determined by the evaluation data conveyed by the decision makers at the beginning of the data input stage. Finally, a novel method is introduced to rank the fuzzy appropriateness indices for choosing the best technology transfer strategy.

The third earliest example about the application of fuzzy MCDM is the consumer purchasing selection. Forecasting consumer purchases of homes, cars, consumer electronics and appliances, and vacations is of great importance to many sectors of the world economy. To address this concern, studies of consumer perception of business conditions are continuously being conducted to help predict these purchases. In Yager et al. [10] suggest a methodology for using information obtained by market surveys to predict the values of other related (linguistic) variables of interest to market research analysts. Based upon a use of Shannon's entropy [11], Yager et al. [10] suggest a measure for calculating the relative predictive powers of two linguistic variables. Yager's OWA operators are used to carry out aggregation of single concepts to form complex concepts. Finally, they select the best predictive model by finding the one which has the minimum entropy. With the help of a survey of respondents on their attitudes toward some present and future economic conditions the authors illustrate the suggested mechanism. In this case study, respondents were asked to rate each of five economic conditions as being good, normal, or bad. A follow-up survey was conducted six months later to determine whether or not they had purchased a house, a car, an electrical appliance or had taken a vacation in the preceding six months. Using the data obtained from this survey, Yager et al., [12] construct a model to best aggregate the respondents' answers to the questions on economic conditions as a predictor of their purchasing a house, car etc. As a result of the process they found, for example, that the best predictor of the home purchases was consumers who rated three economic conditions as good, while the best predictor of car purchases was consumers who rated only two economic conditions as good.

4.2. Some Recent Applications

The applications of fuzzy MCDM are further developed all over the globe across all continents. In the following examples, we discuss some recent practical applications of fuzzy MCDM that have been empirically tested in Malaysia. The several examples perhaps would explains the applications to the categories prescribed in Section 3 even though it is not suffice to act as a representative for each category due to its broad and diverse techniques.

Under the category of finding a ranking, Abdullah and Jamal [13] conducted an experiment to elicit linguistic judgment over the health related problematic status of elderly people. Three decision makers comprise a medical officer and two nurses were voluntarily formed a group of experts. All decision makers were attached at a Malaysian government funded hospital. Decision makers were asked to express their opinion in health related problem among the elderly people based on a guided interview. The closed ended questions of interviewing process were developed by the authors based on literature in health related quality of life and also the SF-36 questionnaire. There were eight indicators of in the questionnaire and decision makers need to make their decisions about the health related problem with respect to eight health related indicators among elder people. The eight indicators used in the case study are Physical-functioning (A), Role-physical (B), Bodily pain (C), Vitality (D), Social (E), Emotional (F), Role-emotional (G), Workplace (H). Decision makers need to respond in five linguistic scales from ‘never has a problem’ to ‘always has a problem’ to indicate their views over experiences of health related symptoms of eight indicators among elderly people. Linguistic responses from the experts were compromised using arithmetic mean to obtain average weight score and the score for indicator A was (1.89, 2.67, 3.67). The centroid-point of A was computed using a computer algebra system. Finally the centroid-point for indicator A is obtained as 2.743333334 after executing the proposed steps. The centroid-points for seven other indicators were computed with the same fashion. The indicators were ultimately ranked in ascending order according to the magnitude of the centroid-point. Based on the magnitudes, ranking of the indiactors are finally obtained as $A \prec D \approx F \prec G \prec B \prec H \prec E \prec C$ where the symbol $\prec$ represents 'has less problem than' and the symbol $\approx$ represents 'has equal problem as'. Physical-functioning, Emotional and Vitality were among the indicators that portrayed less problematic indicator among elderly people. Ultimately ranking is used to decide the gradation of a problematic level among elder people.

Under the category of the comparative importance of multi-attributes, Abdullah et al., [14] propose a new Fuzzy MCDM model by hybridizing Intuitionistic Fuzzy Set (IFS) with the Analytic Hierarchy Process (AHP). The AHP is inherently a subjective process, which involves uncertainties in the evaluation and affects the process of decision making. Meanwhile the notion IFS can handle vagueness type of uncertainties. As to this, Abdullah et al., [14] has proposed a new decision making method in Fuzzy MCDM by considering the uniqueness of pair-wise comparison in AHP and the complementary of memberships in IFS. The concept of IFS in AHP has been introduced through pair-wise comparisons. A ranking order has been obtained via IFS-AHP evaluation process by using positive and negative components of IFS in the concept of AHP. The application of IFS-AHP certainly can help decision makers to make more realistic and informed decisions based on available information. Under the same category, Abdullah and Jamal [15] investigate the weights for health-related quality of life indicators among chronic kidney diseases patients. Patients' perceptions of the impact of disease and treatment and the indicators such as physical, psychological, social function and well being are normally investigated. In this research, the application of the fuzzy decision making method in ranking indicators of HRQoL among kidney patients. Four experts in health fraternity were selected as decision makers to elicit information regarding health related status of chronic kidney disease patients over eight HRQoL indicators. The decision makers were required to rate the regularity of experiencing health-related problems in linguistic judgment among the patients. The five linguistics variables were used as input data to a modified version of Fuzzy Simple Additive Weight decision making model. The modified six-step method was possible to tap the extent of decision makers' opinions on the severity of HRQoL experienced by the patients. Weights for each indicator were computed and conclude that the indicator of role-physical recorded the lowest problematic level while the indicator of mental health recorded the highest problematic level experienced by the patients.

The third category presents an example of the applications of fuzzy linear regression in road accident problems. This predictive analysing was investigated by Zamri and Abdullah [16] where modelling accidents behaviour was the ultimate aim. In this research, a fuzzy regression was employed to estimate number of road accidents in Malaysia. To show the applicability of the fuzzy regression, statistics of road accidents from the year 1974 until 2007 were used, trained and tested. The standard indicators used in the fuzzy regression algorithm were population, registered vehicles, road lengths and road accidents. Finally a fuzzy linear regression model with three independent variables was obtained. Another application of fuzzy programming was conducted by Abdullah and Zakaria [17] . The model of matrix-driven fuzzy linear regression was proposed as to overcome the computational risk and was successfully tested in a civil engineering application. This research extends the application of the model to investigate the relationship between variables that impacting car sales volume. The variables of petroleum prices, population, Gross Domestic Product (GDP) and Gross National Product (GNP) are predicted with the response variable of car sales volume. Thirty years' time series data of the variables from various Malaysian agencies were used as input data into the models. It is found that the model successfully yield a fuzzy linear regression equation as to explain the relationship between predictors and response variable. It also noticed that eighty eight percent variations in car sales volume attributed by the price of petroleum, population, GNP and GDP. The model also successfully explained the contributions of left and right errors of fuzzy numbers of regression coefficients to the car sales volume. The fuzzy numbers that represent the coefficients of regression certainly offer a new contribution to the relationships between the variable of car sales volume and the four predictors.

The recent some applications of fuzzy MCDM are farther than enough to reflect the huge contributions of fuzzy MCDM in real life applications. Nevertheless it is suffice to provide a showcase of the importance of fuzzy MCDM decision sciences.

5. Conclusion

Presence of decision making was heavily felt in line with development of the vague and uncertain theory of fuzzy set theory. This paper has provided a review of MCDM categories and fuzzy MCDM categories. Pioneering applications of fuzzy MCDM were discussed as it gives an impetus to develop a larger scale of research in this field. Finally this paper ends with several real life applications in Malaysia as to illustrate the applications out of the huge techniques in each category. Knowledge of fuzzy MCDM is anticipated to be succeeded along with the tremendous development in fuzzy sets, fuzzy logic and various innovative intelligent techniques in MCDM.

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