FUZZY DECISION BY OPINION SCORE METHOD (FDOSM): DESIGN AND DEVELOPMENT OF NEW MULTI CRITERIA DECISION MAKING METHOD

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ABSTRACT

The purpose of this research was to design and develop a new multi-criteria decision-making (MCDM) method called Fuzzy Decision by Opinion Score Method (FDOSM) to help overcome the problems of MCDM methods based on the idea of an ideal solution This research used an experimental research design with which FDOSM was applied to individual and group contexts. Essentially, FDOSM contains three main blocks, namely the input data block, data transfer block, and data processing block. For the data processing block, three sets of experiments were carried out to optimize the parameters of the proposed method. The first experiment dealt with three different configurations, namely Direct aggregation, Compromise Rank, and Distance measurement, of a single decision maker. Direct aggregation with arithmetic mean is the main configuration recommended for comparing the results of different experiments. However, if the maximum utility is important to the decision maker, compromise ranking would be the proper configuration. The second experiment focused on the process of Group Fuzzy Decision by Opinion Score Method (G-FDOSM) with two different configurations, namely internal and external aggregation. The main finding of G-FDOSM experiment showed the results of internal and external configurations were close, with the ratio of the closeness of the experimental results of G-FDOSM with 90 alternatives being 71.02%. However, external aggregation was deemed more appropriate for compromise ranking. The third experiment involved several different case studies to examine the suitability of FDOSM in solving different MCDM problems. The results showed that, compared to the ideal solution, the best player (P16) achieved a ratio of 58.3% from the ideal solution, which was considered to be the best ratio among other players for the sports science case study. For the GPS case study, experimental results showed the best solution was m8 with a ratio of 67% from the ideal solution. Overall, the results of FDOSM and G-FDOSM were close to the human’s opinions, suggesting that arithmetic mean is the most suitable aggregation operator for all the experiments and FDOSM can adopt different fuzzy membership. Furthermore, reference comparison used with FDOSM can be implemented more efficiently compared to the use of the pairwise comparison of the Analytic Hierarchy Process and the Best-Worst Method. In conclusion, the proposed FDOSM had been successfully modulated mathematically, tested with different numerical examples, and compared to other MCDM methods.

KEPUTUSAN KABUR DENGAN KAEDAH SKOR PENDAPAT: SATU REKA BENTUK DAN PEMBANGUNAN BARU KAEDAH MEMBUAT KEPUTUSAN PELBAGAI KRITERIA

ABSTRAK

Tujuan kajian ini adalah untuk mereka bentuk dan membangunkan satu kaedah baru yang dinamakan Keputusan Kabur dengan Kaedah Skor Pendapat (Fuzzy Decision by Opinion Score Method, FDOSM) untuk mengatasi masalah yang berkaitan dengan kaedah membuat keputusan pelbagai kriteria (MCDM) berdasarkan ide penyelesaian yang ideal. Kajian ini menggunakan reka bentuk penyelidikan eksperimen di mana FDOSM digunakan dalam konteks individu dan kumpulan. Pada asasnya, FDOSM mempunyai tiga blok, iaitu blok data input, blok pemindahan data, dan blok pemprosesan data. Bagi blok pemprosesan data, tiga set eksperimen dijalankan untuk mengoptimum parameter kaedah yang dicadangkan. Eksperimen pertama melibatkan tiga konfigurasi yang berbeza, iaitu Pengagregatan Langsung, Kedudukan Kompromi, dan Pengukuran Jarak yang melibatkan pembuat keputusan tunggal. Pengagregatan Langsung dengan min aritmetik adalah konfigurasi utama yang disarankan untuk perbandingan keputusan eksperimen yang berbeza. Namun, jika utiliti maksimum adalah penting untuk pembuat keputusan, pemeringkatan kompromi adalah merupakan konfigurasi yang lebih sesuai. Eksperimen kedua melibatkan proses membuat keputusan kumpulan (G-FDOSM) dengan menggunakan dua konfigurasi yang berbeza, iaitu pengagregatan dalaman dan luaran. Dapatan utama untuk eksperimen G-FDOSM menunjukkan dapatan konfigurasi dalaman dan dapatan konfigurasi luaran adalah hampir sama di mana nisbah kedekatan antara dapatan G-FDOSM dengan 90 alternatif adalah 71.02%. Namun, pengagregatan dalaman adalah lebih sesuai untuk pemeringkatan kompromi. Eksperimen ketiga pula melibatkan beberapa kajian kes yang berbeza untuk menentukan kesesuaian FDOSM dalam menyelesaikan masalah MCDM. Dapatan menunjukkan pemain P16 mencapai nisbah sebanyak 58.3% berbanding dengan penyelesaian ideal yang merupakan nisbah yang terbaik jika dibandingkan dengan lain-lain pemain dalam kajian kes sains sukan ini. Untuk kajian kes GPS, dapatan experimen menunjukkan penyelesaian yang terbaik adalah m8 dengan nisbah sebanyak 67% berbanding dengan penyelesaian ideal. Keseluruhannya, dapatan FDOSM dan G-FDOSM adalah hampir sama dengan pendapat manusia, dan ini menyarankan min aritmetik sebagai pengendali pengagregatan yang paling sesuai untuk semua eksperimen dan FDOSM boleh menggunakan keahlian kabur yang berbeza. Tambahan pula, perbandingan rujukan yang digunakan bersama FDOSM boleh dilaksanakan dengan mudah berbanding dengan penggunaan perbandingan berpasangan Proses Hierarki Analitik (AHP) dan Kaedah Terbaik-Terburuk (BWM). Sebagai kesimpulan, kaedah FDOSM yang dicadangan telah dimodulasi secara matematik, diuji dengan contoh berangka yang berbeza, dan dibandingkan dengan kaedah MCDM yang lain dengan jayanya.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
CP	Critical Path
DM	Decision Maker
FDOSM	Fuzzy Decision by Opinion Score Method
G-FDOSM	Group- Fuzzy Decision by Opinion Score Method
FMCDM	Fuzzy Multi Criteria Decision Making
FTOPSIS	Fuzzy Techniques for order preference by similarity of ideal solutions
GDMs	Group Decision Makers
GM	Green Manufacturing
HRM	Human Resources Management
ICT	Information and Communications Technology
IS	Ideal Solution
IVIFN	Interval Value Intuitionistic Fuzzy Number
MADM	Multi Attributes Decision Making
MCDM	Multi Criteria Decision Making
NIS	Negative Ideal Solution
NPD	New Product Development
OI	Open Innovation
PIS	Positive Ideal Solution
PSP	Personal Selection Problem
R&D	Research and Development

SAW	Simple Additive Weighting
SC	Supply Chains
SCM	Supply Chain Management
TFNs	Triangular Fuzzy Numbers
TOPSIS	Techniques for Order Preference by Similarity of Ideal Solutions
DAAM	Direct Aggregation with Arithmetic Mean
DAGM	Direct Aggregation with Geometric Mean
DAHM	Direct Aggregation with Harmonic Mean
RMS	Direct Aggregation with Root Mean Square
CR	Compromise Ranking
DiM	Distance Measurement

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter presents the direction of our work, a brief background about the research, the problem statement, the research objectives, and the scope research.

In Section 1.2, a brief background about the research is presented. In Section 1.3, present the problem statement. In Section 1.4 and Section 1.5, present the research objectives and the research scope. Finally, in Section 1.6 present the outline of this study.

1.2 Problem Background

One of the most important topics in expert system and operations research is fuzzy multi-criteria decision making (FMCDM) (Mardani et al., 2015), which contains a number of decision alternatives and decision criteria. The objective of MCDM is to locate the most eligible alternative(s) among a set of alternatives with the chosen criteria. MCDM techniques can solve selection problems in a wide domain of engineering (Abd et al., 2014; Aghaie et al., 2011), economics (Javadian et al., 2009; Park et al., 2011), management problems (Singh & Benyoucef, 2011; Vahdani, Mousavi, et al., 2011; Vahdani et al., 2013), and other fields such as medical (Baykasoğlu & Gölcük, 2015; Y. Feng et al., 2016) sports science (J. Li & Zhang, 2009; X. Liu & Chang, 2010), networking (Xing et al., 2009; Z. Xu & Zhang, 2013), etc.

In MCDM problems, the qualitative characteristics depend upon the DM judgment. Selection is often based on unsuitable data or personal judgment because of the ambiguity of a human being’s thought which leads to wrong and biased decisions. FMCDM techniques can suitably explain the DM evaluation of existing alternatives for selecting the best alternative when the criteria have subjective perceptions. Therefore, the evaluation process preferably solved under a fuzzy environment in order to consider the linguistic variables (Cables et al., 2012; Chamodrakas et al., 2009; T. W. Liao, 2015; Singh & Benyoucef, 2011; Vahdani, Mousavi, et al., 2011; T.-C. Wang & Lee, 2009). The uncertainty and subjectivity in MCDM methods can result in weighting errors and difficulties in the process of criterion weight acquiring (J.-H. Huang & Peng, 2012; Joshi & Kumar, 2016). In many real-world problems, the decision makers cannot give numeral values to the judgments of comparison because the human preference pattern is uncertain. Fuzzy set theory has been successfully used in decision-making problems to solve the extreme vagueness that emerges in the data from human judgment and preference (Benitez et al., 2007; Cables et al., 2012; Cheng & Lin, 2012; Hatami-Marbini et al., 2013; Igoulalene et al., 2015; Krohling & Campanharo, 2011; Park et al., 2011; Rashid et al., 2014; Sadr et al., 2015; Z. Xu & Zhang, 2013; S. Zhou et al., 2012).

In MCDM, various techniques are used to solve problems, one of the most popular in mathematical approach is the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The core idea of TOPSIS is to choose the best solution by simultaneously measuring the distances of each alternative to the positive ideal solution (PIS) and the negative ideal solution (NIS). PIS is an alternative and is the most preferred solution by decision makers (DMs) in maximising benefit criteria and minimising cost criteria. NIS is the least preferred solution in maximising the cost criteria and minimising the benefit criteria. The preference order is then built according to which alternative is closest to PIS and farthest from NIS, resulting in a scalar criterion that combines the two distance measures and the best alternative (Roszkowska & Wachowicz, 2015). On the other hand, MCDM techniques contain DM preferences and subjective judgments, including quantitative and/or qualitative criteria ratings, in addition to the weights of criteria. However, these issues can be imprecise, indefinite and uncertain, making the decision-making process complicated when applied to real-world problems (Vahdani, Mousavi, et al., 2011).

1.3 Problem Statement

In general, the MCDM techniques divided into two approaches, the first approach depended on the human preference such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Best-Worst Method (BWM) etc. The second approach is depended on mathematical operations such as TOPSIS, Simple Additive Weighting (SAW), etc. However, each approach has its own drawbacks.

Many techniques in the MCDM field suffer from the abundance of mathematical equations, the large number of mathematical equations lead to incorrect decision (Sihai Guo et al., 2015; Hsu et al., 2015; Jahan et al., 2012; Senouci, Hoceini, et al., 2016; R. Sun et al., 2016). As a result, the number of mathematical processing was lower whenever the decision was closer to humans.

TOPSIS technique works on principle of the Ideal Solution (IS), and commonly used in different fields, however, TOPSIS suffer from several problems, in particular, normalization, where different normalization techniques result different ranking for alternatives (Sihai Guo et al., 2015; Hsu et al., 2015; Jahan et al., 2012; Senouci, Hoceini, et al., 2016; R. Sun et al., 2016). In addition to that literature review point at the weight as one of the TOPSIS drawbacks (X. Bao, Qu, Dong, Wang, & Sheng, 2015; Jianyu Chu & Su, 2012; Ding, Shao, Zhang, Xu, & Wu, 2016; Du & Yu, 2008; S. Guo et al., 2015). Another drawback reported by the researchers is the distance measurement suffers from problems (i.e. the benefit and cost criteria, the actual value). (Hsu et al., 2015; Jahanshahloo et al., 2006; Kuo, 2016; Shyur, 2006).

In addition to, uncertainty information, incomplete information, and ambiguity in information are also open challenges due to the fact that, decision-makers use linguistic terms and weight cannot be determined in real numbers. The problems mentioned above are reported frequently in the academic literature (J.-H. Huang & Peng, 2012; Mishra, 2016; T.-C. Wang et al., 2007; Z. Xu & Zhang, 2013) (Chamodrakas et al., 2011; T.-Y. Chen, 2011; Hatami-Marbini et al., 2013; G. Lee et al., 2014; Vahdani et al., 2013). Other mathematical approach methods share similar the same problems addressed with TOPSIS technique.

On the other hand, the human approach (the methods that involve human preferences to produce the final decision), suffered from several problems. Perhaps, on the most tremendous challenge in this approach is the inconsistency ratio generated from the pairwise comparisons (Benítez et al., 2014; Destercke, 2018; Ergu et al., 2014; Koczkodaj & Urban, 2018; Morgan, 2017). Due to the number of the pairwise comparisons in this approach, time consuming is considerably high (Ayağ & Özdemir, 2009, 2012; Ebrahimian et al., 2015; Jadhav & Sonar, 2011). Not to mention, the uncertainty resulted from human subjectivity (Ayağ & Özdemir, 2009). Therefore, real number is not allows fit to solve multi criteria decision making problems.

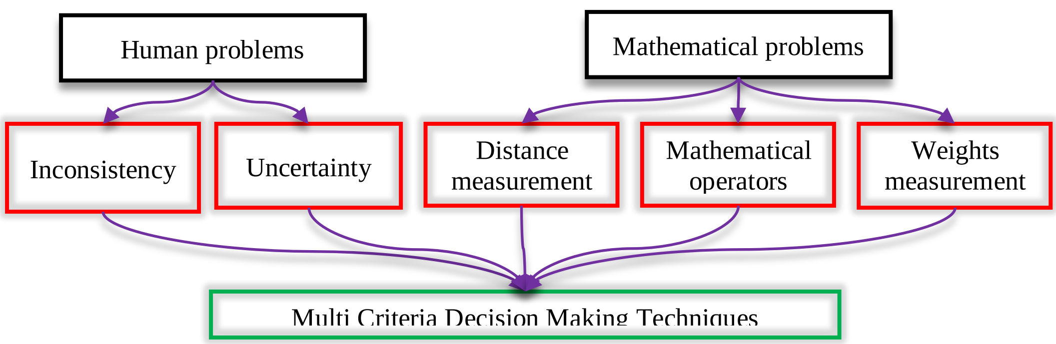

Figure 1.1. Type issues in multi criteria decision making

To summarize the main issues in MCDM, there are two type of issues, namely, issues related data (i.e. inconsistency and uncertainty) and issues related to mathematical operations. See Figure 1.1.

On the other hand, other challenges are related to aggregating the result when the case required group decision makers (Junying et al., 2009; H.-C. Wang et al., 2015).

To overcome the problems mentioned above, a new MCDM method must consider the idea of ideal solution, avoid multiple references, reduce the number of comparisons, define fair and implicitly understandable comparisons, avoiding inconsistency, reduce the uncertainty and finally minimum number of mathematical operations.

Therefore, this research is an attempt to design and develop a new multi criteria decision making method by utilizing the idea of ideal solution and opinion matrix in the fuzzy environment to overcome the mentioned issues.

1.4 Research Objectives

This research aims to design and develop new multi-criteria decision making approach. Towards this end, the objectives below are proposed:

1. To investigate the academic literature related to MCDM, in particular, Fuzzy TOPSIS via systematic literature review.

2. To design and drive a mathematical model for new decision method namely Fuzzy Decision by Opinion Score Method (FDOSM).
3. To develop FDOSM in group decision making environment, Group Fuzzy Decision Opinion Score Method (G-FDOSM).
4. To apply FDOSM on different multi criteria decision making problems, practically (computer networking, sports science, and GPS).
5. To evaluate and compare FDOSM with AHP, BWM, and TOPSIS.

1.5 Research Questions

There are several questions addressed from the problem statement section. This research proposed to answer the following questions:

1. What are the issues discussed with scope of multi criteria decision making techniques that used the idea of ideal solution?
2. What are the type of comparison applied with MCDM methods?
3. Is opinion matrix resulted from FDOSM easier to understand? Comparing with pairwise and reference comparisons?
4. How to aggregate the opinion matrix into ranking order?
5. How to aggregate the opinion matrix into group decision making environment?
6. What is the advantage of using FDOSM over AHP, BWM, and TOPSIS?

1.6 Significance of Study

Decision making is one of the major human activities, and one of the unavoidable tasks of managers. The decision situation is solved by adoption of a decision, which represents a selection of one action out of solutions available. The significance of decision making reflects in the fact that even if none of the possible solutions and actions have been chosen, the decision has been made - it has been decided not to choose or to do nothing (Šporčić, 2012). The major benefit of MCDM methods is that local optima corresponding to one objective can be avoided by taking into account the whole spectra of objectives, leading thus to a more efficient overall process. So, MCDM and help people reflect upon their choices and focus on objectives and tradeoffs (Jancic-Stojanovic et al., 2009).

1.7 Research Scope

The scope of this study can present in the following points.

1. The literature review focus on the Fuzzy TOPSIS method only, whereby, the Ideal Solution (IS) is utilized.
2. Different study cases from different fields are adopted from academic literature to explain the usability of the new theory.
3. Analytical Hierarchy Process (AHP), Best-Worst Method (BWM), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are selected because they used human preference and mathematical operations respectively.

1.8 Outline of Study

This study consists of eight chapters; Chapter One provided a background about the multi-criteria decision making and TOPSIS, problems statement, research objective, and the scope of this study, the rest of the thesis is organized as follows:

Chapter Two: In Chapter Two, in-depth investigation was conducted for multi criteria decision making and FTOPSIS. This includes defining the terms we used in our development in particular, MCDM and TOPSIS and Fuzzy. A systematic review protocol is developed for literature review to analyses the challenges and develop a taxonomy for the research articles in the area of MCDM.

Chapter Three: In Chapter Three, technical problems with examples related to human and mathematical approach of MCDM techniques is reported.

Chapter Four: In Chapter Four, research methodology and scenarios of proposed method for both single and group decision making is designed. In addition to that, the mathematical module of each scenario and the study cases are proposed in this chapter.

Chapter Five: In Chapter Five: experimental result for single decision maker scenarios is presented alongside with related discussion and its claims/findings.

Chapter Six: In Chapter Six: experimental result for group decision making scenarios is presented alongside with related discussion and its claims/findings.

Chapter Seven: In Chapter Seven, we applied FDOSM on different case studies, to ensure the applicability of FDOSM and its capacity of handling different multi criteria decision making problems in different fields. Examples in this chapter covered different cases and utilized different fuzzy membership functions in particular, Trapezoidal fuzzy membership and Triangular fuzzy membership.

Chapter Eight: Chapter Eight is the conclusion chapter of this thesis. This chapter identified the main goals and how these goals achieved thoroughly, the contribution and the main finding, research limitation, and finally, recommendation for the future works. Figure 1.2, shown the outline of study briefly.

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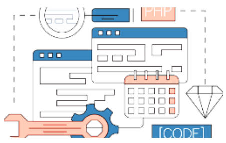
Chapter One

- Research Introduction

Chapter Two

- Systematic Reveiw



Chapter Three

- Issues Related to Human and Mathematical MCDM Approaches

Chapter Four

- Research Methodology Phases

Chapter Five

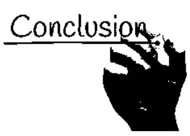
- Single Decision Maker

Chapter Six

- Group Decision Making

Chapter Seven

- Case Study and Comparitive Analysis



Chapter Eight

- Conclusion

Figure 1.2. Outline of The Study