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ORIGINAL ARTICLE

Research gaps in multi-criteria decision making methods for researchers as an areas of interest

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ABSTRACT – The increase in multi-criteria decision-making studies is reflecting its importance as an interesting area for research. Even though a high number of revealed studies mainly in last decade, still this field has challenges that require attention from researchers in future studies. Most of multi-criteria decision-making studies either have not considered determining decision maker's weights or applied subjective methods to derive these weights. In addition, the absence of implementing sensitivity analysis to decision maker's weights is noticed. Furthermore, there is a need to develop new methods that utilizing the web or mobile technologies to deal with complexity and uncertainty adhered to multi-criteria decision-making problems. This paper represents a trial to list current challenges in this field as areas of interest for researchers in future studies.

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INTRODUCTION

Multi-Criteria Decision-Making (MCDM) is an acritical process that tackles problems to select the best solution (alternative) concerning predefined criteria [15]. As per Arian et al. [16], The MCDM methods can be grouped as: (1) Value Measurement Methods, like SAW (Simple Additive Weighting); (2) Goal or Reference Level Models, such as TOPSIS (Technique for Order Performance by Similarity to Ideal Solution); (3) Outranking Techniques, like PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations).

Emrah and Kabak [22] reviewed MCDM studies during the period of 47 years from 1970 to 2016, they revealed that an increasing trend in studies focusing on MCDM mainly after the year 2006. And by referring to Web of Science, the figures for the years 2017-2019 were added, as presented in figure (1).

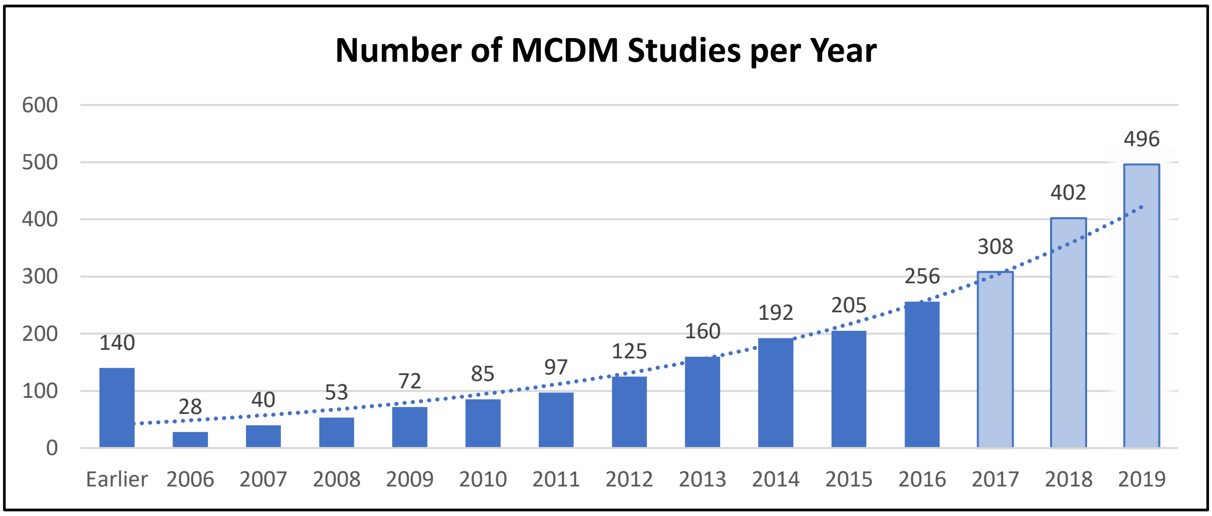

Figure 1 Distribution of MCDM Studies Between 2006 and 2019

When Comparing different MCDM methods, it was found that TOPSIS is one of the dominant MCDM methods due to its simplicity to understand and implement compared to outranking methods such as ELECTRE and PROMETHEE [29]. In table 1, TOPSIS is compared with other methods [16], where TOPSIS has a moderate level in calculation, simplicity and stability. Brauers and Zavadskas [35] Suggested that using two or three different methods could lead to more robust optimization results than using a single method.

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Table 1 Comparison Between Different MCDM Methods

MCDM method	Computational time	Simplicity	Mathematical calculation	stability	Information type
MOORA	Very less	Very simple	Minimum	Good	Quantitative
AHP	Very less	Very critical	Maximum	Poor	Mixed
TOPSIS	Moderate	Moderate critical	Moderate	Medium	Quantitative
VIKOR	Less	Simple	Moderate	Medium	Quantitative
ELECTRE	High	Moderate critical	Moderate	Medium	Mixed
PROMETHEE	High	Moderate critical	Moderate	Medium	Mixed

After reviewing models supporting Sustainable Supplier Selection (SSS), Zimmer et al. [47] reached to that TOPSIS is the foremost MCDM method among others, that because of its easiness to understand and implement as well, compared to outranking methods. Added that, combining TOPSIS with IFS could enhance the process to deal with uncertainty, fuzziness and imprecise information.

In general, there are two types of uncertainties; intrapersonal uncertainty and interpersonal uncertainty that are defined by Mendel and Wu [30]. Where intrapersonal uncertainty relates to judgment understating for each individual decision-maker, while interpersonal uncertainty is the judgment variation between different decision-makers.

The use of linguistic terms to solve the MCDM problem would be more realistic than numerical values directly [44]. Decision-makers prefer to provide their preferences by using linguistic terms than numerical values due to its simplicity [24].

The solution of the MCDM problem is derived from the preferences of a group of decision-makers, and due to the vagueness and imprecise in the available information, Decision-makers use IFNs to give preferences and build decision matrix [11].

Zadeh [45] proposed the fuzzy set theory (FS) that granted a good attention in several fields. Then, the intuitionistic fuzzy set (IFS) was introduced by Atanassov [2] as a broad view of the FS theory that possessed more attention since being developed. Vague set as another generalization of fuzzy sets was introduced by Gau and Buehrer [14] where Bustince and Burillo [5] pointed out that vague sets and IFS are the same. then. Atanassov and Gargov [3] proposed the interval-valued intuitionistic fuzzy sets (IVIFSs) as a broad view of IFS.

In the MCDM problem, there are multiple criteria where their weights have a significant role in evaluating different alternatives [10]. Criteria weights affect the final ranking order of the alternatives and the aggregation process as well [13]. The methods of assigning criteria weights could be divided into two categories: subjective, based on decision-makers comments (AHP is the commonly used method), and objective, like using the Entropy method [16] like Shannon entropy method [34]. Hatefi [17] suggested to derive criteria weights based on decision matrix (preference values) instead of DMs direct evaluations to the criteria, by considering the “Dispersion Logic” that gives less weights to criteria with similar values among alternatives.

Assigning a single decision-maker to solve MCDM problems would be hard due to the variety and complexity nature of such problems [4]. In reality, a group of decision-makers has to tackle most MCDM problems [19]. Having a team with similar knowledge, experience and thought is impossible in most cases; therefore, assigning equal weights for decision-makers could affect the reliability and effectiveness of the final results [22].

Koksalmis and Kabak [22], they reviewed the MCDM studies for 47 years (1970 – 2017), and found that 76% of the studies that are concerned to determine decision-makers weights had published after 2011. And claimed that this subject still has good attention by researchers since the last few years. Even though, that 82% of the studies used static weights, they expected that dynamic weighting methods will be dominant in future studies. Figure 2. Presents the number of MCDM studies concerned with deriving decision-makers’ weights from Koksalmis and Kabak study up to 2017, and for 2018-2019 figures from Web of Science.

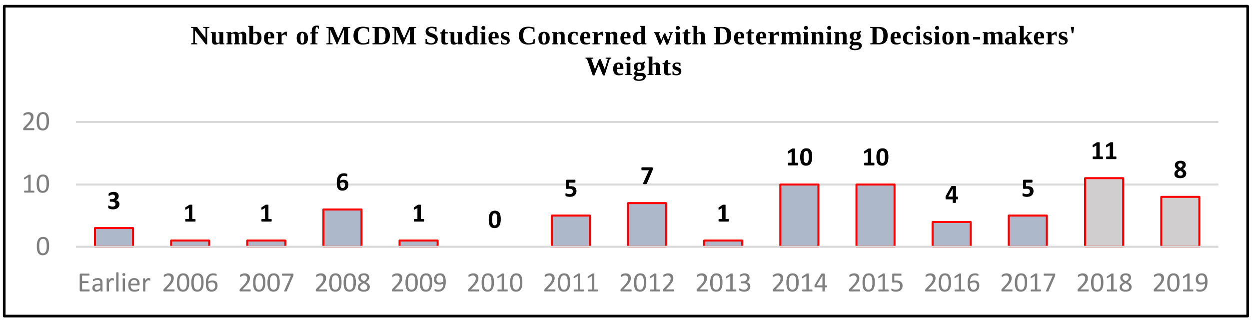

Figure 2 Distribution of MCDM studies concerned with the determination of the decision-makers’ weight (2006 – 2019)

CHALLENGES

1. Assigning decision weights objectively:

Currently, Kabak and Ervural [31] mentioned that only 41% of current studies considering the decision-makers weights and almost all studies assigned weights directly using subjective rating method, and none of them delivered a comprehensive objective method for determining the weights. More objective methods are required [16].

Koksalmis and Kabak [22], they reviewed the MCDM studies for 47 years (1970 – 2017), and found that 76% of the studies that are concerned to determine decision-makers weights had published after 2011 (fig. 2). And claimed that this subject still has good attention by researchers since the last few years. Even though, that 82% of the studies used constant weights, they expected that dynamic weighting methods will be dominant in future studies.

But the challenge is how to treat the variety inconsistency with a group of decision-makers [20]. However, normally decision-makers weights are not considered in the MCDM literature [28, 42]. Liu et al. [26] added that irrationality of the MCDM processes increased due to not considering decision-makers' weights or supposing its known. Hence, defining a process to detect weights is crucial and motivated research topic [7, 40].

As an example of the frequently used subjective technique to determine the decision-makers weights is the equation (1) that proposed by Boran et al. [12], where the weights are detected based on the subjective evaluation from senior management $D = (\mu_k, v_k, \pi_k)$:

$$\lambda_k = \frac{\left(\mu_k + \pi_k \cdot \left(\frac{\mu_k}{\mu_k + v_k}\right)\right)}{\sum_{k=1}^{m}\left(\mu_k + \pi_k \cdot \left(\frac{\mu_k}{\mu_k + v_k}\right)\right)} \tag{1}$$

The above equation was used by different studies like; Yalcin and Kilic [39], Memari et al. [29], Sachdeva and Kapur [21].

Other studies used TOPSIS, statistical variance (SV) and simple additive weighting (SAW) to obtain the decision-makers' weights as an objective weighting process [25, 26]. Both subjective and objective weighting methods still the weights are constant and not dealing with errors that may take place due to that decision-makers may be biased or a sudden errors may take place [28].

2. Criteria weights:

A group of DMs may face difficulties to agree on assigning exact criteria weights, a large number of attributes could reduce the accuracy of their subjective weights [33]. For that, Hatefi [17] added that using objective or semi-objective techniques that are few in this field, even there are techniques like; Entropy, Standard Deviation, Ideal Point and Maximizing Deviation, but still there is a need for analytical techniques to handle situations where there is no preferences information from DMs.

DMs normally selected from different fields where they characterized by different skills, knowledge and experience, so, it's not rational for DMs to set criteria weights based on their information [11].

3. Sensitivity analysis:

One of the simplest ways to check out how the solution of an MCDM problem varies with the changes in the criteria and decision-makers' weights is sensitivity analysis [1]. A well-designed sensitivity analysis determines the inputs that require more care and have a limited effect on the problem solution [1]. There are many pieces of research [9, 38] employed sensitivity analysis to conduct the effect of changing either criteria weights or aggregated methods separately or together. Most of the studies did not implement sensitivity analysis on decision-makers' weights [22].

4. MCDM method with Intuitionistic fuzzy set based:

MCDM methods are usually used to select the best alternative according to the different criteria (multi-attributes) [38]. The aim is to provide decision-makers' an efficient and rational decision technique to comprehensively analyze all objective and subjective criteria of the problem [36, 40]. Researchers started using fuzzy set theory and intuitionistic fuzzy set theory to achieve more accurate results and to deal with imperfect and imprecise data [28]. And the fuzzy MCDM area is a hot research field [37].

5. A virtual MCDM method based DSS:

Decision support systems (DSS) could enhance the decision making process's effectiveness by making better and quick analysis and decision, in addition to dealing with complex and imprecise data [8, 22]. A need for a web or mobile technology applications based DSS could draw attention of future studies. The rationale behind using mobile applications to solve MCDM problems is that enhancing the communication will positively affect the MCDM decision, by making the discussion more concentrated on the problem rather than less important issues [18].

CONCLUSIONS

Ideally, the process followed to tackle MCDM problems should have the following characteristics: (1) a simple employed method (or a combination of methods) in its understanding and calculation. (2) Having objective decision-makers' weights that deal with uncertainties and biases of the expert team and their judgments that consider assigning specific decision-makers' weights for different criteria. (3) Developing criteria weights objectively based on the evaluation decision matrix. (4) allow to conduct sensitivity analysis for criteria and decision-makers' weights to determine the critical areas of the process.

Developing objective techniques to determine weights for decision-makers' and criteria is still needed, and will be an area of interest. In addition to inherent sensitivity analysis for these weights to enhance the validation of the selected solution.

Facilitating the communications between a group of experts could be achieved by utilizing the web or mobile-based technology, which would give the decision-makers' the chance to work and meet virtually to provide the best solution for MCDM problems.

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