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Method Article

Upgrading current multi-attribute decision-making with a 3-dimensional decision matrix for future-based decisions



Shahryar Sorooshian

University of Gothenburg, Gothenburg, Sweden

A B S T R A C T

Two shortcomings of existing Multi-Attribute Decision-Making (MADM) approaches are presented in this paper. The problems were decision makers' (experts') dynamic level of experience in certain areas, as well as the difficulties of forecasting the future with the existing MADM techniques. A solution is also proposed to overcome the issues.

- Two critical shortcomings of existing multi-attribute decision-making (MADM) approaches are presented with this work.
- As a solution for the shortcomings, a 3-dimensional decision matrix is introduced.

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A R T I C L E I N F O

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E-mail address: shahryar.sorooshian@gu.se

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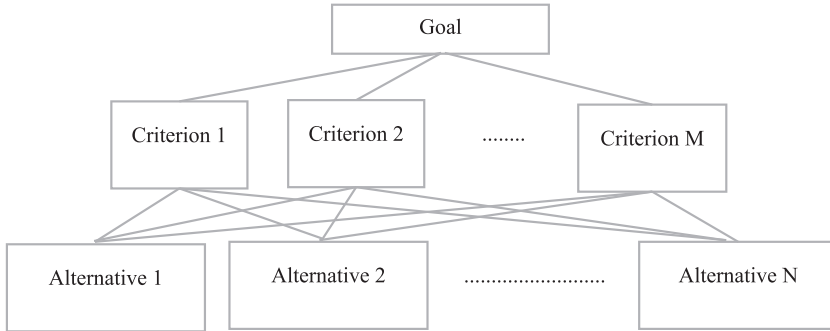


Fig. 1. Hierarchical structure of MADM.

Method details

Introduction

MADM (Multiple Attribute Decision Making) and MODM (Multi-objective Decision Making) are sub-categories of MCDM (Multi-Criteria Decision Making, also may be called MCDA or multi-criteria decision analysis) from the operational research category of applied mathematics [1]. This study focuses on MADM methods, such as TOPSIS, ELECTRE, PROMOTEE, VIKOR, etc. They are characterized as methods for dealing with a discrete set of alternatives with the goal of evaluating them via a list of criteria in order to rank them from best to worst, or just identify the best one, as well as appointing them to specified ordered groups [2].

Accordingly, Fig. 1 presents this hierarchical structure of MADM for N alternative and M decision criteria.

MADM is a widely used technique in decision-making across a broad range of fields and topics, according to its definition. The use of such MADM has steadily increased over time, with an especially noticeable increase in complex decision-making areas [2–4]. Even today, MADM decision-making is widely used in a wide range of critical issues [4–6]. MADM, on the other hand, is designed to perform decisions in static environment, which is one of their limitations. Hashemkhani Zolfani et al [6] explain that in order to address classic MADM, the decision is believed to have happened without considering that the legitimacy of decisions would be jeopardized, as MADM refuses to accept the fact that values shift with time and in different circumstances [6]. The complexity of the current decision environment leads to the increased dynamic character of the decision elements [4], but MADM declines probabilities and uncertainties when deciding about the future.

Dynamic decision environment and decision making for the future are interconnected topics [3,5]. The majority of real-world decisions should be made in a dynamic environment, the future can shift conditions easily, decision criteria are dynamic so the MADM must be with this extra care [6]. Hence, MADMs' capability is constrained and a new pattern should be added to the existing MADM techniques which are related to decision-making for the future with dynamic conditions [3,5,7,8] and obviously, MADM's status could not be saved without this new pattern [5,6].

However, the revamped MADM based on potential expectations is now the key challenge [3]. Thus, this report will concentrate on this theme and will emphasize how MADM and its structure will vary in diverse situations and frameworks for future-based decisions in a dynamic environment.

Revamped MADM

In general, MADM problems are represented in a matrix structure known as the decision matrix [9,10]. A decision matrix is a $N \times M$ matrix in which component A_{ij} indicates the output of alternative i as compared to decision criterion j (for $i = 1$ to N and $j = 1$ to M). Fig. 2 summarizes this

	Criterion 1	Criterion 2	Criterion M
Alternative 1	$A_{1,1}$	$A_{1,2}$	$A_{1,j}$	$A_{1,M}$
Alternative 2	$A_{2,1}$	$A_{2,2}$	$A_{2,j}$	$A_{2,M}$
....	$A_{i,1}$	$A_{i,2}$	$A_{i,j}$	$A_{i,M}$
Alternative N	$A_{N,1}$	$A_{N,2}$	$A_{N,j}$	$A_{N,M}$

Fig. 2. Classic Decision Matrix.

detail best. Hence, if an upgraded matrix accepts and converts dynamic inputs with future prediction consideration to the classic decision matrix, MADM, with no additional swap, is revamped. Here 2 considerations are proposed to upgrade the decision matrix for this purpose.

Consideration 1: There is insufficient evidence for future-related decision making so a panel of experts is often the medium for MADM. But there have never been enough reviews on assessing experts who collaborate in a MADM [8]. Typically, it is up to the investigators to invite qualified experts in the area of analysis, and it can be multi-disciplinary as well [8]. A decision panel with full confidence in their expertise can be difficult to find in dynamic, complex, or multidisciplinary, or interdisciplinary issues. As a solution, Sorooshian [11] proposed an extension to MADM that grade individuals of the panel of experts where they have a non-equal level of expertise or different

	Expert's level of confidence (L) for judging alternative i	Criterion 1	...	Criterion M			
		Optimistic estimation	most likely	Pessimistic estimation	Optimistic estimation	most likely	Pessimistic estimation
Alternative 1	L_1	$A_{1,1,O}$	$A_{1,1,ML}$	$A_{1,1,P}$	$A_{1,M,O}$	$A_{1,M,ML}$	$A_{1,M,P}$
	L_i	$A_{i,1,O}$	$A_{i,1,ML}$	$A_{i,1,P}$	$A_{i,M,O}$	$A_{i,M,ML}$	$A_{i,M,P}$
	L_N	$A_{N,1,O}$	$A_{N,1,ML}$	$A_{N,1,P}$	$A_{N,M,O}$	$A_{N,M,ML}$	$A_{N,M,P}$

Fig. 3. Three-dimensional Decision Matrix.

confidence level (L). These grades (which, for example, can range from 0 to 100) will be multiplied by their responses.

Consideration 2: For considering that the future may not go as predicted, the program/project evaluation and review technique (PERT) has a well-known statistical outlook. It is defined with three points for future estimations where a Beta distribution represents the prediction function. Such a distribution would have a single peak, with the most likely estimate, ML, representing that value. Similarly, it was thought that there is a low probability that either the optimistic or pessimistic estimates, O and P, will come true. As a result, O and P are correlated with low probabilities. There is no inference taken regarding the location of the most likely estimate in relation to positive or negative predictions. It is free to take any stance between the two extremes, based solely on the decision maker's discretion [12]. Hajdu & Bokor [13] say, in this three-point estimation approach the approximation of the predictions is calculated by (optimistic estimate + 4 (most likely estimate) + pessimistic estimate) /6.

Finally, with the addition of the two listed considerations, the classic decision matrix will be upgraded to a three-dimensional decision matrix, as seen in Fig. 3.

Demmons, Rohlinger, and Heiman [14] explain that the weight for each parameter in the decision-making matrix is often decided by the decision-maker based on the needs of the base's goal. Thus, after the collection of data from each individual in the panel based on the designed decision matrix, analysis for data from each expert follows two steps:

1. Consideration of level of expertise/confidence
2. approximation of the predictions based on the three-point estimation practice

To sum up, the decision matrix for each expert would be based on modified value for each cell where $A_{i,j} = L_i \times (A_{i,j,O} + (4 \times A_{i,j,ML}) + A_{i,j,P})/6$ is the formula. In group decision-making, the average of all $A_{i,j}$ gathered from experts will be taken into account for group MADM.

Conclusion

Although the MADM mathematical methods for processing the relevant data are relatively straightforward, quantifying these data is the challenge [9]. With this paper, some modification for data collection and decision matrix construction in MADM in general and regardless of any specific MADM technique is proposed to enable future-based decision making with a dynamic panel with a non-equal level of expertise. With this modified 3-dimensional decision matrix, the problem of unbalanced expertise in group decision-making plus uncertain future forecasting is addressed. But the quest for the best decision-making approach can never be complete, so more research in this field remains crucial.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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