A Hybrid Multi-Criteria Decision Support Model: Combining DANP with MDS

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Abstract. Human beings encounter the problem of making decision in their daily life. However, most decision makers, when encounter the decision problems involving multi-criteria or diverse alternatives, they could not make correct decision due to lacking related decision-making information. Therefore, what is most concerned by the decision makers is how to pick out the most optimal decision-making evaluation factors and the best execution alternataive for a multi-criteria decision making (MCDM) problem. This study combined the merits of various decision-making analytic methods, namely, decision making trial and evaluation laboratory (DEMATEL), analytic network process (ANP) and Multidimensional Scaling (MDS), so as to propose a four-stage Hybrid Decision-Making Support Model (HDMSM) to assist the decision makers in making the best decision when they face a decision problem.

Keywords: Multi-Criteria Decision Making, Analytic Network Process, Decision Making Trial and Evaluation Laboratory, Multidimensional Scaling.

1 Introduction

Human beings encounter the problem of making decision all the time in their daily life. Most of these decision problems involve many factors that are to be evaluated by a decision maker, and there are usually many alternatives for one decision problem (Simon, 1977). However, most decision makers, when encounter the decision problems involving multiple evaluation factors or alternatives, often fail to make correct decision due to lacking related information (Hwang & Yoon, 1981). Therefore, what is most concerned by the decision makers is how to pick out the most optimal decision-making evaluation factors and further find out the best execution alternataive for a multi-criteria decision making problem (Yoon & Hwang, 1985).

In the field of decision science, multi-criteria decision making (MCDM) methods are most frequently used to solve the above-mentioned decision problems (Belton, 1990). The objective of MCDM methods is to help the decision makers express their preferences structure from limited number of possible alternatives, and then use

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various multi-criteria decision-making analytical methods, such as DEMATEL, AHP and so on, to convert the qualitative value of each evaluation criterion and alternative into quantitative weight (Buede & Maxwell, 1995), and finally, according to the priority ranking, determine the important decision-influencing factors and the ideal execution alternative (Opricovic & Tzeng, 2004). MCDM methods have been rapidly developed in the fields of management and social science in recent years, and have been widely employed in, for example, investment portfolio (Ehrgott, et al., 2004), supplier selection (Shyur & Shih, 2006), and green supply chain (Büyüközkan, 2012).

While there are numerous researches and applications of MCDM methods. However, these methods still have several disadvantages need to be improved. First, each of the MCDM methods has its own theoritical basis as well as its merits and drawbacks. As a result, when different methods are used for the same decision problem, they would usually lead to different results, so that the decision makers are at loose ends (Keeney, 1992). Therefore, it is very important that how to combine a veriety of MCDM methods in order to develop a decision support model for effectively assisting the decision makers in making a correct decision (Yang, et al., 2008). Second, the diversified social environment makes the decision problem much more complicate. In the current environment of decision problem, the evaluation factors frequently have interaction or conflict with each other, and the conventional hierarchy-based MCDM methods just could not accurately help the decision makers evaluate the factors in such decision problems (Saaty & Vincke, 1988).

In view of the above fact, ANP is one of the important MCDM methods that used in the multi-criteria decision making to effectively handle the dependence and feedback among different evaluation factors (Saaty, 2001). Before using ANP to measure the weights of the evaluation factors, a networking among all factors must first be established (Wu, 2008). However, the establishment of the networking is not included in the scope of ANP. Therefore, it need other analytical methods to find out the relation between different factors (Yang & Tzeng, 2011).

ANP can help the decision makers to find out what are the critical evaluation factors in the decision problem; DEMATEL can establish the relation between the evaluation factors; and MDS can be used in multi-alternative decision to analyze the similarity between different alternatives and further assists the decision makers to more accurately find out the most optimal alternative (Huang, 2005). The objective of this study is to combine the merits of the above three decision-making methods, so as to propose a Hybrid Decision-Making Support Model (HDMSM) to assist the decision makers in making the best decision when they face a decision problem.

2 Literature Review

2.1 Decision Making Trial and Evaluation Laboratory

Decision making trial and evaluation laboratory (DEMATEL) was originated from the Geneva of the Battelle Memorial Institute in 1973. It can effectively observe the level of mutual influence among different factors, so as to understand the complicated cause-and-effect relationship in the decision problem Fontela & Gabus (1976). The analytic process are shown as follow.

Define the Relationship among Evaluation Factors. Through literature review or brainstorming, then, listing the factors which affect the problem of decision-making, and interview the experts who are in the related field, in order to determine the relationship between each of two factors.

Establish Direct-Relation Matrix. If the decision problem with n evaluated factors, according to the degree of influence scores which is determined by experts, further, to establish an $n * n$ direct-relation matrix, which represent as Z. Among the matrix, z_{ij} represent the degree of the factor z_i effect factor z_j. The calculation is in equation (1).

$$Z = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} 0 & z_{12} & \dots & z_{1n} \\ z_{21} & 0 & \dots & z_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \dots & 0 \end{bmatrix} \end{array} \tag{1}$$

2.2 Analytic Network Process

ANP is a decision-making analytical method that uses network and nonlinear structure to represent a decision problem, and is developed in response to the fact that many decision problems could not be presented with the structured hierarchy. The main objective of ANP is to correct the traditional AHP, with which the problems of dependence and feedback might occur between the criteria or the layers (Saaty, 1996).

ANP mainly through Supermatrix to show the relationship and strength of graph among factors. The best advantage of using Supermatrix is it can evaluate the external and internal of dimensions dependability efficiently. In addition, we can obtain the weight of each factors through the Limit Supermatrix.

2.3 Multidimensional Scaling

Multidimensional scaling (MDS) is a data reduction method, it uses the distance or similarity between data points to locate the spatial coordinates and the relative positions of several given data in the low-dimensional space (Torgerson, 1952).

M-MDS is mainly through compute the Euclidean distance between each two factors, and show all factors in Perceptual map which has two dimensions. The similarity between two factors more stronger, the configuration of two factors more close in the map. As a result of graph can show factors more clearly and let researchers understand easily. Therefore, Through Perceptual map could show the hidden structure or spatial relation between the factors, and achieve the classification result through the spatial difference.

3 Hybrid Decision-Making Support Model

This study proposes a Hybrid Decision-Making Support Model (HDMSM). As shown in Figure 2, the decision-making procedures according to HDMSM includes

total four stages, namely, Selection, Relation, Evaluation and Decision, which are described below:

Selection. From literature, proper evaluation criteria and alternatives are selected for the goal in the decision making.

Relation. To understand the relation among different evaluation criteria, it is necessary to further use the DEMATEL method to analyze the degree of mutual influence among different criteria.

Evaluation. Based on the relation among different criteria as found in the stage II, a networking structure of evaluation is plotted. Then, according to the networking structure of evaluation, an ANP expert questionnaire is designed and distributed. Further, using ANP to analyze and calculate the weights and the priority ranking of the evaluation criteria.

Decision. Use ANP to process all the evaluation criteria and the alternatives, so as to pick out the most optimal alternative and calculate the Euclidean distance among the alternatives. Then, use MDS to analyze and find out the similarity and dissimilarity among all the alternatives.

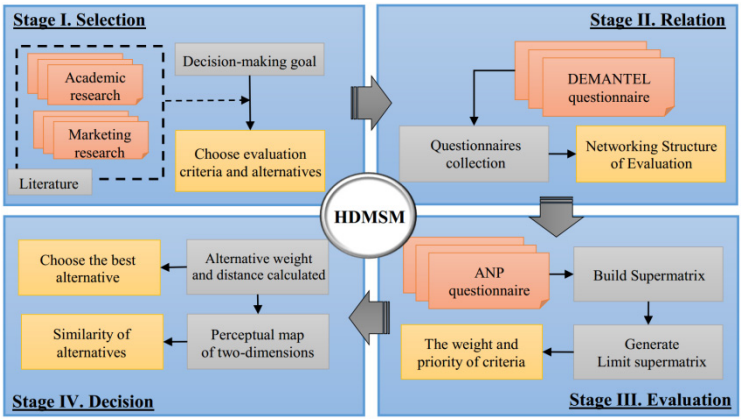

Fig. 1. Hybrid Decision-Making Support Model (HDMSM)

4 The HDMSM with Sample Demonstration

4.1 Criteria and Alternatives Selection

Before a multi-criteria decision making, it is necessary to select the criteria suitable for use as evaluation factors and to select the alternatives. The criteria can be obtained from past similar decision problems or related literature. In this study, we postulate five evaluation criteria (C1~C5) and five alternatives (A1~A5) for explaining the subsequent sample decision-making flow according to our HDMSM.

4.2 Establishment of Criteria's Relationship

After the criteria are selected, first distribute the DEMATEL expert questionnaire, so as to determine the relation and the degree of mutual influence among the criteria. The adopted scaling is the 0~3 scaling designed by Fontela & Gabus (1976); where, 0 indicates there is not any relation among the criteria, and 3 indicates there is significant relation among the criteria. Table 1 shows a sample questionnaire of DEMATEL.

Table 1. The Questionnire Sample of DEMATEL

	C1	C2	C3	C4	C5
C1	-	3	0	1	1
C2	0	-	2	2	0
C3	0	1	-	0	3
C4	2	0	0	-	2
C5	0	0	1	3	-

4.3 Plotting of Networking Structure of Evaluation

After the process using DEMATEL method, the criteria's relationship presented in the obtained results is used to plot a networking structure of evaluation, a sample of which is shown in Figure 3.

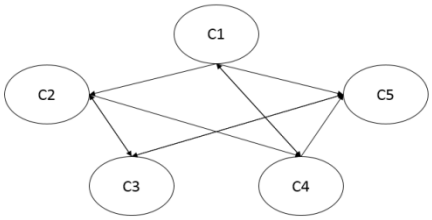

Fig. 2. The Sample of Networking Structure of Evaluation

Further, distribute the ANP expert questionnaire that is designed based on the networking structure of evaluation. For example, when use C1 as a basis of evaluation, a pairwise comparison is conducted among C2, C4 and C5. The questionnaire is rated on the Pairwise Comparison Scale proposed by Saaty (Saaty, 1980), as shown in Table 2.

Table 2. The Sample of Pairwise Comparison

Important <---------- Equal ----------> Important										
Scale	9:1	7:1	5:1	3:1	1:1	1:3	1:5	1:7	1:9	Scale
C2						V				C4
C2				V						C5
C4		V								C5

4.4 Criteria Weighting and Priority Ranking

The collected ANP expert questionnaires are calculated to acquire the eigenvectors of criteria and to form a Supermatrix. Through normalization of the Supermatrix and complex matrix multiplication, a Limit Supermatrix showing weights of the evaluation criteria can be obtained. A sample Limit Supermatrix is shown in Table 3.

Table 3. The Sample of Limit Supermatrix

	C1	C2	C3	C4	C5	Weight	Rank
C1	0.230	0.230	0.230	0.230	0.230	0.230	3
C2	0.338	0.338	0.338	0.338	0.338	0.338	1
C3	0.249	0.249	0.249	0.249	0.249	0.249	2
C4	0.033	0.033	0.033	0.033	0.033	0.033	5
C5	0.150	0.150	0.150	0.150	0.150	0.150	4
Total	1.000	1.000	1.000	1.000	1.000	1.000	-

4.5 Multidimensional Scaling and Alternative Selection

Normally, there is more than one alternative for a decision problem, for each alternative, different evaluation criteria usually have different importance levels. Therefore, after obtaining the criteria's priority ranking, it is necessary to further calculate the relative importance level of each alternative based on the evaluation criteria, so as to facilitate the subsequent alternative similarity analysis. Again, the pairwise comparison scale proposed by Saaty is used as the rating scale. Finally, the total weight and the priority ranking of each of the alternatives based on all criteria are obtained, as shown in Table 4.

Table 4. The Sample of Alternatives Priority

	C1	C2	C3	C4	C5	權重總合	Rank
A1.	0.473	0.170	0.111	0.134	0.554	1.442	1
A2.	0.059	0.055	0.423	0.095	0.102	0.733	4
A3.	0.036	0.117	0.162	0.043	0.231	0.589	5
A4.	0.149	0.396	0.271	0.480	0.064	1.361	2
A5.	0.283	0.262	0.033	0.249	0.048	0.875	3
	1.0000	1.0000	1.0000	1.0000	1.0000	-	-

Based on Table 4, the Euclidean distance between any two alternatives can be further calculated to create a Euclidean distance matrix, as shown in Table 5.

Table 5. The Sample of Euclidean Distance Matrix

	A1	A2	A3	A4	A5
A1	0.000				
A2	0.699	0.000			
A3	0.557	0.302	0.000		
A4	0.736	0.546	0.567	0.000	
A5	0.566	0.522	0.419	0.383	0.000

From the Euclidean distance matrix, we can find the coordinate positions of the alternatives in a second dimension and plot a perceptual map, as shown in Figure 4.

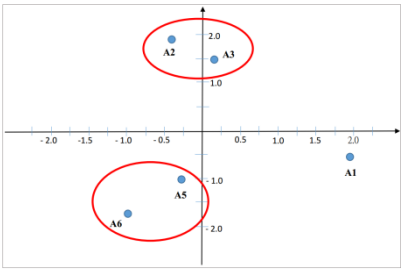

Fig. 3. The Sample of Perceptual Map

From the perceptual map, the decision maker can have a clear idea about the similarity and the dissimilarity among all the alternatives. Finally, along with the priority of the criteria and the alternatives to select the most optimal alternative.

5 Conclusions and Further Work

MCDM problem has always been a topic that can not be ignored in many different fields, such as management, social science and even engineering. The main objective of decision analysis is to help decision makers determine the evaluation criteria and find out the most optimal alternative for their decision problems.

This study combines three different MCDM methods, namely, DEMATEL, ANP and MDS, to propose a four-stage hybrid decision-making support model (HDMSM). This model can be used to effectively analyze the relational level among different evaluation criteria in a decision problem, and to find out the criteria that have most significant influence on the decision results. Then, the criteria and the decision alternatives are cross-analyzed to help the decision makers pick out the best alternative for the decision problem for execution.

The HDMSM can be applied to analyze decision problems of various issues, such as system introducing or business process reengineering. In future, HDMSM could be combined with other decision methods in order to improve the accuracy and effectiveness of this decision-making support model in handling decision problems.

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