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Modelling for Causal Interrelationships by DEMATEL

Siti Aissah Mad Ali, Shahryar Sorooshian and Cheng Jack Kie

Faculty of Industrial Management
Universiti Malaysia Pahang, Malaysia

Abstract

This paper aims to propose researchers and professionals to employ DEMATEL as an essential element in their decision making process. Effort is taken to make it apparent that DEMATEL would be the most suitable tool when there is composite and complex mixture of aspects or factors relationship that has to be understood prior making any decision. The interdependencies could be well understood by having the Impact Relation Map chalked out via DEMATEL. This visualization with the calculations that shows the degree of impact would very well furnish decision makers with aiding information. In this paper, DEMATEL's capability and method will be detailed out for general understanding and guidance.

Keywords: DEMATEL, MCDM, Causal Interrelationships, IRM

1. Introduction

Decision making, especially in the operational or management area is never something to be taken simple. Having decision making perceived less important is not far from putting the system where decision making is required into lines approaching failure. Any effort into improvement would be worthless if they're not accurately decided where or on which operation of a system should it be executed; end up being a waste of effort or even a threat to the system if the decision made is poor.

Basically decision making could be interpreted as a process or a study of alternatives to decide on the best effort to be implemented based on the criteria, values, preference, experience, goals, objectives, desires, values and et-cetera [2].

Generally decision making process could be explained on the generalized procedural basis: step 1 - define problem, step 2 – determine requirements, step 3 – establish goals, step 4 – identify alternatives, step 5 – define criteria, step 6 – select a decision making tool, step 7 – evaluate alternatives against criteria and finally to validate solutions against problem statement [2]. This paper looks into the fifth step which brings us to two classifications: single criterion decision making and multi criteria decision making. Our focus is to be adjusted to fall on the latter; multi criteria decision making and a tool to assist one throughout this paper.

Decision criteria must be based on goal(s) to enable discrimination among alternatives. It should be perceived as an objective measure on how well each of the alternative would achieve the understood and agreed goal. Minimally there's at least one decision criterion for each goal, but as the goal's complexity increases, it could generate more than that.

Decisions can be based on either single or multiple criteria. Usually, it is simpler to come to a conclusion on decisions when it involves just one measure. Optimization could be rather easier when the objective function comprises of just one criterion. Nemhauster et al [22] has mentioned that there are many techniques that could be adopted for the solution, linear programming and et-cetera depending on the form and functional description of the problem; where decision has to be made.

However, the focus of this paper neglects on the single criterion decision making as the real business and management in the actual industry life does not deal with one but many criteria. It is never very simple when it comes to decision making in real life as one decision will impact not only one operation or practice but will also lead to another. This phenomenon is called as multi-criteria decision making (MCDM); where we have finite number of criteria on infinite number of alternatives [33].

MCDM isn't anything new to the world especially in the industry. Many MCDM methods have been introduced to this world such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Goal Programming (GP), Multi-attribute Utility Theory (MAUT), Multi-attribute Value Theory (MAVT), Elimination and Choice Expressing Reality (ELECTRE) and et-cetera [32]. The method we are to dive into in this paper is DEMATEL.

2. DEMATEL

DEMATEL is abbreviated from Decision Making Trial and Evaluation Laboratory. It forms as a comprehensive method where the causal relationship of the criteria can be constructed into a structural model and analyzed further [17] [6]. This method was first put into action at the Battelle Memorial Institute in Geneva for the purpose of studying and solving the complicated and intertwined in a complex system which affects a large group of stakeholders with multiple factors or decision criteria [9] [22]. DEMATEL has been applied and proved to be a good and successful MCDM in many areas such as control systems, project management, strategies, operations management and et-cetera [3] [5] [7] [26] [27] [29] [30] [31].

It has the capability to solve complex problems by enhancing the understanding of complicatedly interacted factors and criteria. This shall then lead and direct to the construction of a hierarchical relevant network system which shall then be used to solve the complex problems [16] [7]. Putting it simple, DEMATEL could be employed to construct and Impact-Relation Map (IRM) as well as to identify and realize the influence levels of each elements over the other [8]. By knowing the nature and degree of influence an attribute or criterion has on each other, the reflection on the system's characteristics could be comprehended [1]. Making a decision without understanding neither the external nor internal reality are going to be detrimental to the organization, depending on the importance, complexity and impact of the decision made to the organization. Hence, it is important to gain this understanding to have better decisions made with executive capability [17] [35]. As mentioned, this scientific research method will at the end enable us to construct the Impact-Relation Map to verify the relationship among the indicators (IRM) [1] [17] [35]. Prior to employing the DEMATEL method, it is vital to have the criteria or factors. This shall then be used as a pre-step into the DEMATEL. Procedures on conducting DEMATEL can be summarized as the diagram in figure 1 based on the work of a few researchers [20] [24] [36] [34] [4] [6].

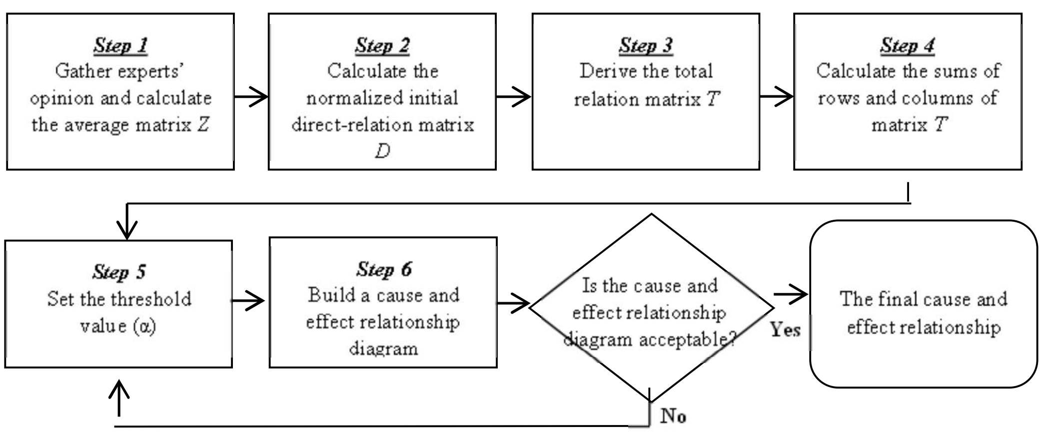

Fig. 1; DEMATEL steps

STEP 1: Gather Expert's Opinion and Calculate the Average Matrix ***Z***

Let's consider a group of m experts and n factors for this study. Experts are to be given a list of factors arranged in sets of i and j. They're then to be asked to indicate their believed degree of impact the factors have on each other (pair-wise comparison); how does factor i affects factor j. The indication can be made on the scale of 0-3; 0 = no influence, 1 = weak direct influence, 2 = moderate direct influence, 3 = strong direct influence. However, this scale is just an example as to be used in this paper, otherwise, the rating scale is subject to the researcher's preference.

The degree to which the expert perceive factor i affects factor j is denoted as x_{ij}. For each expert, an *n x n* non-negative matrix is constructed as $X^k = [x^k_{ij}]$, where *k* is the expert number of participating in the evaluation process with $1 \leq k \leq m$. The mathematical notation can be formulated as below:

$$X = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & 0 \end{bmatrix}$$

Thus, we would have X^1, X^2, X^3, …, X^m would be the answer matrix obtained from the experts. Each element of the matrices is denoted with x_{ij} representing the degree of impact *i* has on factor *j*. The diagonal elements of each matrix is set to zero as DEMATEL does not evaluate self-influence of factors.

An average understanding on the experts' response has to be reached. This could be done by calculating the average of the matrix which could be called as an initial direct-relation matrix. This matrix could be presented as matrix ***Z*** = [z_{ij}] based on the method below [17]:

$$z_{ij} = \frac{1}{m}\sum_{i=1}^{m} x_{ij}^{k}$$

STEP 2: Normalizing the Initial Direct-Relation Matrix *D*

Normalized direct relation matrix ***D*** then has to be calculated from the average matrix ***Z***. This is done by dividing each element by the largest row sum of the average matrix. Total direct influence on the influence scale of the factor with most direct influence on the other factors can be represented as factor: $max_{1 \leq i \leq n} \sum_{j=1}^{n} z_{ij}$

The value of each element in this normalized direct-relation matrix ***D*** would range between [0,1]. The calculation to obtain the meant matrix is as shown:

$$D = \frac{Z}{s}$$

Where, $$s = \max_{1 \leq i \leq n} \sum_{j=1}^{n} z_{ij}$$

<u>STEP 3: Obtaining the Total Relation Matrix *T*</u>

Employing this step would realize the direct/indirect or total relationship between each pair of the system factors. The assumptions are that the indirect influence matrix converges to the null matrix as shown below:

$$\lim_{k \to \infty} D^k = 0$$

Where 0 is the null matrix with I is an n x n identity matrix, the following hold true:

$$\lim_{k \to \infty} \left(I + D + D^2 + \cdots + D^k \right) = (I - D)^{-1}$$

The total relation matrix T is, therefore, defined as:

$$T = D(I - D)^{-1}$$

<u>STEP 4: Computing Sums of Rows and Columns of Matrix T</u>

Vector R and are to present the sum of rows and sum of columns respective in the total-influence matrix ***T.*** Let vector R be *n* x 1 and D be 1 x *n*. Thus, the sum of row would be calculated as:

$$\left[D_1 \cdots D_n \right] \text{ with } D_j = \sum_{i=1}^{n} t_{ij} \text{ where } \left(j = 1, 2, \ldots, n \right)$$

The sum of column on the other hand will be calculated as follows:

$$\begin{bmatrix} D_1 \\ \vdots \\ D_n \end{bmatrix} \text{ with } D_i = \sum_{j=1}^{n} t_{ij} \text{ where } \left(i = 1, 2, \ldots, n \right)$$

It summarizes both the direct and indirect effects that factor *i* exerts on the other factors. Similarly, if R*j* is the sum of the *j*th column in the matrix ***T***, then:

$$\begin{bmatrix} D_1 \\ \vdots \\ D_n \end{bmatrix} \text{ with } D_i = \sum_{j=1}^{n} t_{ij} \text{ where } \left(i = 1, 2, \ldots, n \right)$$

It summarizes the direct and indirect effects that factor *j* receive from the other factors. When *i* = *j*, the sum (D*i* + R*i*) shows the total effects given and received by factor *i*, thus:

$$\left(D_i + R_i \right) = \sum_{j=1}^{n} t_{ij} + \sum_{k=1}^{n} t_{ik}$$

It represents the degree of importance of factor i in the entire system. The difference indicates the net effects that factor *i* contributes to the system and is shown below:

$$D_i - R_i = \sum_{j=1}^{n} t_{ij} - \sum_{k=1}^{n} t_{ik}$$

Specifically, if (D*i* – R*i*) is positive, the influence factor *i* is a net cause, while if (D*i* – R*i*) is negative, factor *i* is a net receiver.

STEP 5: Setting the Threshold Value, α

Threshold value needs to be set to eliminate elements of minor effects in matrix ***T***. This is done by computing the average of elements in the matrix as such:

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left[t_{ij}\right]}{N}$$

Where N is the total number of elements in matrix T

STEP 6: Building the Impact-Relation Map

As mentioned earlier, DEMATEL in the last effort would be producing an Impact Relation Map. This is constructed by mapping all coordinate sets of (D*1* + R*1*, D*1* – R*1*) to visualize the complex interrelationship. This diagram provides information to the researcher on which are the most important factors and the influence [24]. The factors that T*ij* is greater than α are selected and shown in cause and effect diagram.

3. Conclusion

This paper proposes DEMATEL as an efficient and most suitable tool to be employed during decision making where it involves making apparent the inter-relationship among factors. At times it is very important to have the causal relationship being visualized for better visibility and comprehension of the real situation. However, in the recent years, there have been many efforts to come up with Hybrid DEMATEL which incorporates some other MCDM into DEMATEL such as ANP, TOPSIS, VIKOR and ZOGP. This even proves how better flexible and effective DEMATEL could be. It is strongly proposed to employ DEMATEL in decision making approaches to assist decision makers in making better decision.

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