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# Understanding Applications and Best Practices of DEMATEL: A Method for Prioritizing Key Factors in Multi-Criteria Decision-Making

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## ABSTRACT

Decision Making Trial and Evaluation Laboratory (DEMATEL) method is a powerful tool for understanding and visualizing the causal relationships among factors in complex decision-making problems. The method uses diagrams and matrixes to map out the causal relationships and interdependencies among factors, allowing decision-makers to identify key drivers and potential solutions to the problem. DEMATEL has a wide range of application areas, including supply chain management, environmental planning, healthcare, finance, and engineering, among others. The DEMATEL method is a valuable tool for decision-makers who need to understand the complex causal relationships among factors in order to make informed decisions. The method provides a structured approach for analyzing and prioritizing factors and for identifying potential solutions to complex problems. This paper describes the main features of this method, its application areas as well as the main process steps in the DEMATEL method.

**Keywords:** Decision making; Multi criteria decision making; Multi attribute decision making; DEMATEL; Decision making trial and evaluation laboratory

## 1. Introduction

Decision making trial and evaluation laboratory (DEMATEL) technique is one of the main multi-criteria decision-making (MCDM) methods that is used

to visualize complex causal relationships' structures through its diagrams or matrixes. This MCDM method was developed in the "Geneva Research Centre of the Battelle Memorial Institute" at the end of 1971 by Gabus and Fontela <sup>[1]</sup> initially. This method has

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received promising attention from many researchers for solving complex decision-making problems in various fields in the past decades <sup>[2]</sup>.

The DEMATEL method works based on structural modeling that is beneficial to analyze cause and effect relationships of the systems' components. In this method, the interdependence among factors can be confirmed, and intertwined and complicated problems can be investigated and addressed. Furthermore, in these problems, the DEMATEL method develops specific maps (charts or diagrams) in order to reflect relative relationships within factors. In this technique, an impact relation diagram is used to find the factors that possess a critical role in a system with a complex structure, and then the priorities of the clarified key factors are determined. In addition, the interdependency relationships are converted into cause and effect groups by using the matrixes. In this process, the end product is called an IRM (the Impact-Relations Map) which is a visual demonstration. The relationship between the criteria's causes and effects is converted into the system's structural and understandable model.

The DEMATEL method can be used to verify interdependence among unpredictable attributes and features and can help to gain a better understanding of practical solutions for problems and complex clusters. It quantifies the relevant degrees/relationships between different elements resulting in understanding the relational structures that help to solve a decision problem. The DEMATEL is based on the vision of using scientific research approaches to enhance the understanding of a particular problem.

The application of feedback is one of the merits of this method compared with others, and all of the factors (instead of just some specific ones) are considered in the structure of this MCDM method <sup>[3]</sup>. Its objective is to investigate, compare, and enhance the factors of the system by dividing them into the groups of cause-effect. The factors' influences on the other ones are examined numerically to find the most effective ones. That is to say, the improvement of cause-groups results to easily improve the effect-group's criteria, and the features of the cause-

group can impact the effect group's aspects simply. Therefore, it is a suitable method for managers who aim to gain high-performance based on the criteria of the effect group in different businesses <sup>[2,4]</sup>.

## 2. Application

The DEMATEL can be applied to a vast range of MCDM problems from computer science to energy and economics <sup>[3]</sup>. The distribution of research articles using the DEMATEL method based on subject area is shown in **Figure 1**. This distribution is gained from the search results for "DEMATEL" in the "ScienceDirect" database based on the articles that include "DEMATEL" in their "title, abstract, or keywords". The results show the application of the DEMATEL method in different subject areas.

Si et al. <sup>[2]</sup> reviewed the application areas of the DEMATEL in their study. They classified the studies based on classical (traditional) DEMATEL into three categories including:

- Type 1: Based on the interrelationships between factors or criteria;
- Type 2: Based on determining the key factors considering the causal relationships and inter-relationship degree between the factors;
- Type 3: Gaining the weights of criteria by considering the interrelationships and impact levels of criteria.

Some examples of the reviewed articles are provided in **Table 1** to gain a better overview of the details of the studies. They also provided the results of DEMATEL application areas as the distribution of the studies in different application areas. Their results identified the main top three areas as computer science (40.6%), engineering (35.7%), and business and management based on the search methodology that they used to identify the articles (26.4%) <sup>[2]</sup>.

## 3. Advantages and disadvantages

Like all developed methods, the DEMATEL method possesses both advantages and disadvantages. The main ones are listed in **Table 2**. Due to the listed disadvantages of DEMATEL, many authors

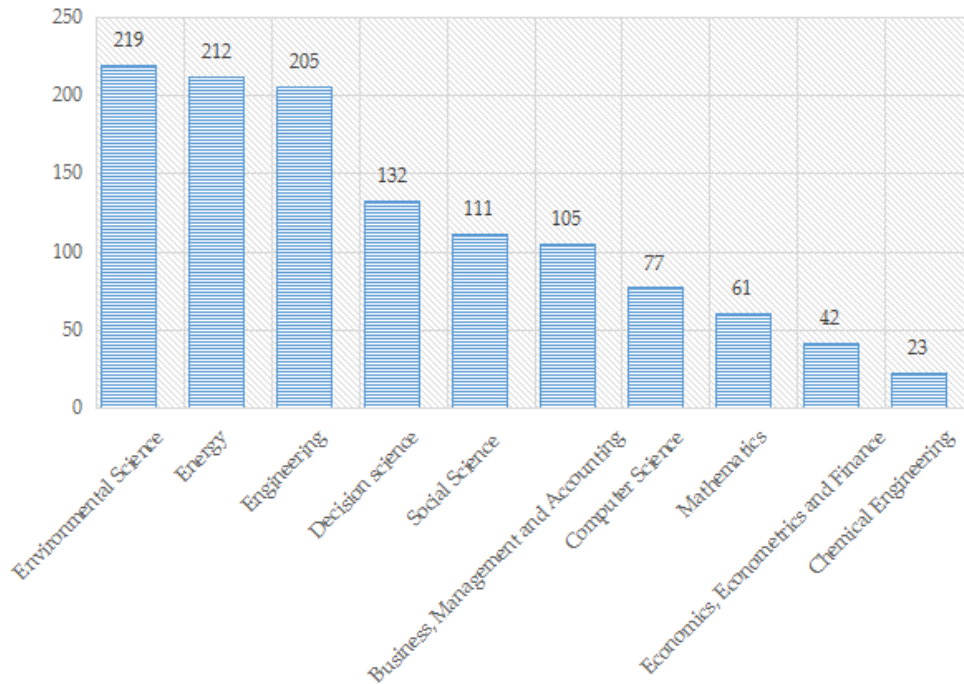


Figure 1. Distribution of DEMATEL application areas.

Table 1. Examples of DEMATEL applications.

Type	Purposes of studies
Type-1: Interrelationships	<ul style="list-style-type: none"> <li>• Determining the degree of the perceived values for patients for healthcare management;</li> <li>• Analyzing the components and dimensions of intelligence in universities based on the cause-effect relations;</li> <li>• Recognizing the interrelationships between different evaluation criteria in specific zones of the railways;</li> <li>• Determining the relationships between the factors of customer buying, and providing marketing strategies in a specific market;</li> <li>• Proposing a model for job satisfaction for a specific industry by considering interactive influences of criteria and the causal relationship of them.</li> </ul>
Type-2: Interrelationships and key factors	<ul style="list-style-type: none"> <li>• Identifying and prioritizing the factors (both affected by and affecting) the enterprises' performances;</li> <li>• Analyzing the relationships of cause and effect for barriers of a specific industry;</li> <li>• Determining the causal relationships between main evaluation indicators, and gaining the most strategic ones for the industries' (such as banking's) performances;</li> <li>• Identifying the causal relationships of factors, and prioritizing them to gain the significant factors for allocation of the resources in organizations.</li> </ul>
Type-3: Interrelationships and criteria weights	<ul style="list-style-type: none"> <li>• Recognizing the cause-effect relationship and evaluating the critical ones for specific processes in industries for example <math>CO_2</math>- capture and storage in the steel industry;</li> <li>• Calculating the relative importance weights for compensatory objective functions;</li> <li>• Recognizing the importance degree of design parameters in a process for example for website design;</li> <li>• Computing global weights for the evaluation indicators to select investing strategies in a specific sector.</li> </ul>

Table 2. Merits and demerits of DEMATEL.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>Analyzing direct and indirect mutual influences among factors;</li> <li>Understanding complex and complicated cause-and-effect relationships;</li> <li>visualizing the interrelationships between different factors by utilizing an IRM;</li> <li>Perceiving the factors that possess mutual impacts (influences) on others;</li> <li>Utilizing to find out the critical criteria for evaluation;</li> <li>Being able to measure the evaluation criteria’s weights;</li> <li>Assuming the criteria dependent;</li> <li>Rational weighting for practical problems considers different weights for each cluster in the weighted super-matrix instead of using equal weights in some other methods.</li> </ul>	<ul style="list-style-type: none"> <li>Although this method considers the interdependent relationships among alternatives, does not incorporate other criteria among them;</li> <li>Does not consider the alternatives’ aspiration level;</li> <li>Does not reach the alternatives’ partial ranking orders;</li> <li>Does not consider the experts’ relative weights to aggregate their personal judgments into group assessments.</li> </ul>

recommend using integrated methods based on DEMATEL and other techniques to address its demerits and benefit from their combined properties [2].

#### 4. DEMATEL process steps

The DEMATEL method can be applied in six main steps. These steps are shown in Figure 2 and are described as follows.

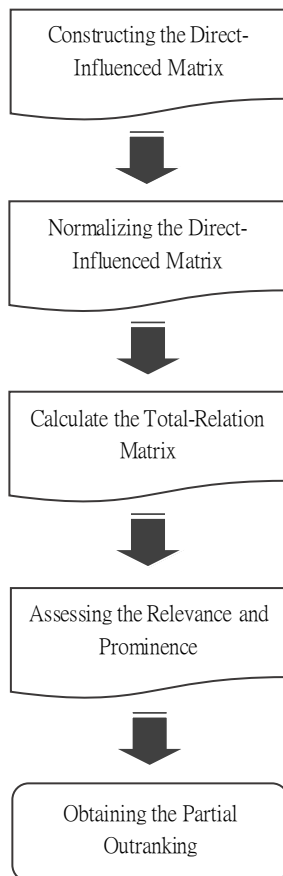


Figure 2. DEMATEL process steps.

Step 1. Average (Direct-relation) Matrix Generation.

In a problem with n criteria (factors), an n×n matrix ( $A_k$ ) can be gained from the  $K^{th}$  expert’s questionnaire/opinion. In this matrix  $a_{ij}(k)$  is the influence degree of criterion  $E_i$  on criterion  $E_j$  determined by the  $K^{th}$  experts. For this decision-makers use a five-level pairwise comparison scale. In this score:

- 0 is for no influence.
- 1 is for low influence.
- 2 is for middle influence.
- 3 is for high influence.
- 4 is for very high influence.

Therefore, these elements create the  $A_k$  matrix as Equation (1):

$$A_k = \begin{bmatrix} 0 & \dots & a_{1n}(k) \\ \vdots & \ddots & \vdots \\ a_{n1}(k) & \dots & 0 \end{bmatrix} \quad (1)$$

If we consider the number of experts as m, then the average matrix Z can be obtained by averaging the scores of the experts. For this:

$$z_{ij} = (a_{ij}(1) + a_{ij}(2) + \dots + a_{ij}(k) + \dots + a_{ij}(m))/m \quad (2)$$

and the average matrix Z is gained as Equation (3):

$$Z = \begin{bmatrix} 0 \dots & z_{1j} \dots & z_{1n} \\ \vdots & \vdots & \vdots \\ z_{i1} \dots & z_{ij} \dots & z_{in} \\ \vdots & \vdots & \vdots \\ z_{n1} \dots & z_{nj} \dots & 0 \end{bmatrix} \quad (3)$$

Step 2. Normalization of the Direct-Relation Matrix.

In this step, Equation (4) is used first:

$$S = \max\left(\sum_{j=1}^n z_{ij}, \sum_{i=1}^n z_{ij}\right) \quad (4)$$

and then the normalized matrix X is:

$$X = Z/S \tag{5}$$

Step 3. Creation of Total Relation Matrix.

In this step matrix  $X$  that can just indicate the direct-relations should be turned into a total-direction or an aggregate relation matrix. For this, a continuous decrease of the problem’s indirect effects besides the power of matrix  $X$  can make convergent solutions to the matrix inversion possible. This is similar to the absorbing Markov chain matrix. For this, Matrix Total ( $T_{n \times n}$ ) is obtained as:

$$\begin{aligned} T &= \sum_{q=1}^{\infty} X^q = X + X^2 + \dots + X^q = X(I + X + X^2 + \dots + X^{q-1}) \\ &= X(1 - X)(1 - X)^{-1}(I + X + X^2 + \dots + X^{q-1}) \\ &= X(1 - X)^{-1}(1 - X^q) = X(1 - X)^{-1}(1 - X^\infty) \\ &= \frac{X}{(1 - X)} \end{aligned} \tag{6}$$

In Equation (6),  $\lim_{q \rightarrow \infty} X^q$  is considered the null matrix ( $[0]_{n \times n}$ ), and the identity matrix is shown as  $I$ . Therefore  $T_{n \times n}$  is:

$$T_{n \times n} = \begin{bmatrix} t_{11} & \dots & t_{1j} & \dots & t_{1n} \\ \vdots & & \vdots & & \vdots \\ t_{i1} & \dots & t_{ij} & \dots & t_{in} \\ \vdots & & \vdots & & \vdots \\ t_{n1} & \dots & t_{nj} & \dots & t_{nn} \end{bmatrix} \text{ where } i, j = 1, 2, \dots, n \tag{7}$$

Step 4. Assessing the Relevance and Prominence.

In Equation (7),  $t_{ij}$  is the total influence (including both direct and indirect-influences) from the criterion  $E_i$  to  $E_j$ . To determine the relevance, the summation of all rows and columns must be calculated by using the following equation:

$$D = [D_i]_{n \times 1} = [\sum_{j=1}^n t_{ij}]_{n \times 1} \tag{8}$$

$$R = [R_j]_{1 \times n} = [\sum_{i=1}^n t_{ij}]_{1 \times n} \tag{9}$$

In Equations (8) and (9), considering  $i = j = k$  the influence of criteria as well as the total extent of being influenced called “prominence” can be calculated by  $D_k + R_k$  (which is the X-axis). In other words, the prominence shows the degree of being influenced by other elements and influences them as well.  $D + R$  also is the central role degree that the elements play in the system. On the other hand,  $D - R$  (called “relation”) is the vertical axis vector demonstrating the net effect that the factor contributes to the system. The relation can be positive or negative. When  $D_k - R_k$  is:

- Negative, the criterion has the tendency toward falling under the causal category (cause-group);
- Positive, the criterion has the tendency toward falling under the result category (effect-group).

Step 5. Setting a Threshold, and Drawing the Diagrams.

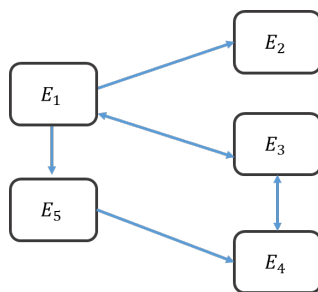
In this step, an IRM is created. The creation of IRM is based on the mapping of ( $D_k + R_k, D_k - R_k$ ) database that adds beneficial insights to the decision-makers. In some situations, however, the IRM can be so complicated and complex that if all of the relations are added, it makes showing the valuable information to the decision-makers hard. In this situation, a threshold value must be set to describe the structural relationship among the criteria and manage complex and complicated problems better. This is used to filter the negligible effects in the  $T$  matrix. Therefore, only the values ( $t_{ij}$ ) in the total relation matrix that are greater than the threshold are considered to show the influences in the cause-effect diagram. For example,  $t_{ij}$  is greater than threshold value then criterion  $E_j$  affects criterion  $E_i$ , and  $t_{ij}$ . If it is less than it, then this value is not selected and not converted in the IRM. This threshold value can be determined by using different methods such as experts’ discussions, brainstorming, the results of literature, averaging the values in  $T$  matrix, and also a method called the maximum mean deentropy (MMDE) (MMDE steps and a numerical example are described in Chen’s work [5]). In low threshold values, the vital information cannot be shown as the diagram can be very complex. In high values, on the other hand, many criteria can be considered independent, and their relationships with other criteria cannot be shown. Therefore, it is important to choose an appropriate value to gain a suitable diagram for cause and effect.

After recognizing the criteria relations (by using the threshold value), a network diagram can be drawn to show the relationships between the criteria simply. Furthermore, in the cause-effect diagram, ( $D + R$ ) is set for the X-axis, and ( $D - R$ ) for the Y-axis. The cause-effect diagram can demonstrate the complicated causal relation. The examples of the

important diagrams gained from the DEMATEL are shown in **Figures 3 and 4**. **Figure 3** is an example of a network diagram that shows the relationship between the criteria in the situation that  $t_{12}, t_{13}, t_{31}, t_{34}, t_{43}, t_{54}, t_{15}, > thresholdvalue$ . In the IRM (**Figure 4**), generally calculating  $(D + R)$  divides the diagram into four parts that give valuable visions to the decision-makers:

- Quadrant 1 includes factors with high relation and prominence that are core factors or intertwined givers;
- Quadrant 2 includes factors with high relation and low prominence that are called driving factors or autonomous givers;
- Quadrant 3 includes factors with both low relation and prominence that are called independent factors or autonomous receivers as they are relatively disconnected from the system;
- Quadrant 4 includes low relation but high prominence that are known as impact factors or intertwined receivers. These factors cannot be enhanced directly and must be influenced by other ones.

Also, the causality diagram of criteria can be drawn with  $(D_k + R_k, D_k - R_k)$  values and by using the relationships shown in **Figure 3** (see an example provided in Chen’s work [5]).

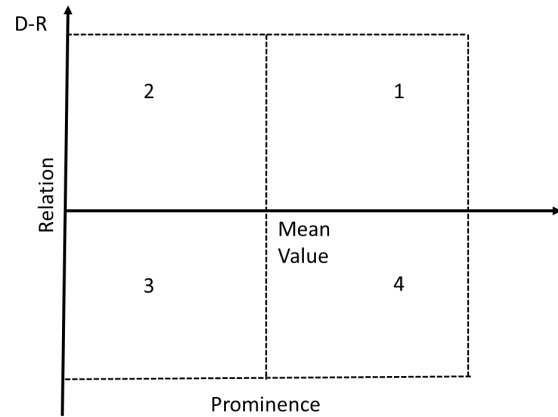


**Figure 3.** An example of a network diagram.

In addition, the weights of the criteria ( $W$ ) can be obtained by Equations (10) and (11) [2,5,6].

$$W_{ia} = \sqrt{(D_i + R_j)^2 + (D_i - R_j)^2} \tag{10}$$

$$W_i = \frac{W_{ia}}{\sum_{i=1}^n W_{ia}} \tag{11}$$



**Figure 4.** IRM with four quadrants.

Source: Adapted from a work by Si et al. [2].

## 5. Conclusions

DEMATEL is one of the main MCDM methods working based on structural modeling that is beneficial for analyzing cause and effect relationships of the systems’ components [3]. This paper provided a survey on the DEMATEL application areas, advantages, and disadvantages, as well as the process steps. This method is beneficial in a vast range of application areas such as engineering, computer science, mathematics, social and decision science, business and management, etc. This method obtained an IRM as the result that provides very helpful information to the decision-makers. The DEMATEL method can be particularly useful in addressing complex and intertwined problems where the interdependency among factors is not straightforward. The method’s ability to develop specific maps or diagrams to reflect the relative relationships within factors makes it a powerful tool for decision-making. Additionally, the method’s feedback feature and consideration of all factors in the system’s structure make it a suitable option for managers aiming to improve their business’s performance. While the DEMATEL method has some limitations, such as the need for expert knowledge and the time required for data collection and analysis, its benefits make it a valuable tool in addressing complex decision-making problems. Overall, the DEMATEL method is a powerful and

versatile tool for decision-making in various fields and can contribute to improving the understanding of complex systems' structures.

## Author Contributions

Conceptualization, Hamed Taherdoost; methodology, Hamed Taherdoost, & Mitra Madanchian; formal analysis, Hamed Taherdoost; resources, Mitra Madanchian; writing—original draft preparation, Mitra Madanchian; writing—review and editing, Hamed Taherdoost; visualization, Mitra Madanchian; supervision, Hamed Taherdoost.

## Conflict of Interest

There is no conflict of interest.

## References

- [1] Gabus, A., Fontela, E., 1972. World problems, an invitation to further thought within the framework of DEMATEL. Battelle Geneva Research Center, Geneva, Switzerland. p. 1-8.
- [2] Si, S.L., You, X.Y., Liu, H.C., et al., 2018. DEMATEL technique: A systematic review of the state-of-the-art literature on methodologies and applications. *Mathematical Problems in Engineering*. 1-33.
- [3] Taherdoost, H., Madanchian, M., 2023. Multi-criteria decision making (MCDM) methods and concepts. *Encyclopedia*. 3(1), 77-87.
- [4] Falatoonitoosi, E., Leman, Z., Sorooshian, S., et al., 2013. Decision-making trial and evaluation laboratory. *Research Journal of Applied Sciences, Engineering and Technology*. 5(13), 3476-3480.
- [5] Chen, C.A., 2012. Using DEMATEL method for medical tourism development in Taiwan. *American Journal of Tourism Research*. 1(1), 26-32.
- [6] Düzgün, M., 2021. Investigation of the criteria affecting the decision of use of drone technology in the logistics sector by DEMATEL method. *Journal of Aviation*. 5(2), 249-264.