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# DEMATEL AS A WEIGHTING METHOD IN MULTI-CRITERIA DECISION ANALYSIS

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**Abstract**

Modelling of a decision-maker's preferences in multi-criteria decision analysis is performed using weights that reflect the relative importance of the given decision criteria. The determination of accurate values of the weights is therefore of considerable importance. Numerous means and methods are used for this purpose, such as: the entropy method (i.e., the method of objective weights), the Simos method, the SWARA method, the ANP or AHP methods, and many others. This paper analyses the DEMATEL method, frequently used to identify cause-and-effect relationships. Nowadays, it is often used in multi-criteria decision analyses. In the opinion of some authors, DEMATEL may be useful also to determine the weights of criteria. However, the approach presented by these authors has certain drawbacks. The present paper proposes a different approach to the weighting procedure using DEMATEL. Using numerical examples, it also presents weights determined by this method and compared to those obtained using the AHP method.

**Keywords:** DEMATEL method, multi-criteria decision analysis, weights of criteria.

## 1 Introduction

Weighting of criteria plays a key role in solving multi-criteria decision problems. As is known, the preferences of the decision-maker related to individual criteria have the form of weights expressing the relative significance of the criteria. In certain circumstances, it is possible to determine weights using the entropy method, as presented, i.a., in papers by Shannon and Weaver (1963) or Ignasiak (2001). The entropy method constitutes a reasonably objective means of defining

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weights, which allows for estimation of the importance of the analysed criteria on the basis of ratings discrepancies of analysed variants with respect to each criterion. Therefore, such methods of weighting are classified in the literature as objective weighting methods (Deng et al., 2000). In general, however, we have to deal with the situation when the some of the criteria are preferred by the decision-maker more than others. Therefore, the entropy method is of little use for criteria weighting.

In such cases, the most profitable method seems that suggested by Simos (1990). It involves determining criteria weights based on the opinion of the group of people using two card sets of the same size (Simos, 1990; Figueira and Roy, 2002). The Simos method has found numerous applications and received positive feedback in solving real-life decision problems.

It should be emphasised that other weighting methods are also known; for example, the SWARA (Step-wise Weight Assessment Ratio Analysis) method (Keršuliene et al., 2010; Zolfani et al., 2013) which allows for the inclusion of experts, lawyers or disputed parties' opinions regarding the significance ratio of the attributes in determining rational decisions.

Still other procedures of weighting criteria are described in the literature, e.g., in the following papers: Solymosi and Dombi (1986); Edwards and Barron (1994); Barron and Barret (1996); Roy and Mousseau (1996); Wang and Zionts (2006); De Almeida et al. (2016).

Another frequently used means of determining weights of criteria is the AHP method (Saaty, 1980), which is a relatively common tool for solving multi-criteria decision problems. It uses a hierarchical structure of the decision problem and is implemented in order to:

- indicate the relative significance of criteria (e.g. global preferences, i.e. criteria weights),
- indicate the ratings of decision-making alternatives relative to individual criteria variants (the so-called local preferences).

In the AHP method, preferences on each level of analysis are indicated by means of a pairwise comparison matrix (matrix P) of the factors specified at this level. Pairwise comparison is conducted using Saaty's relative scale of ranks (Saaty, 1980). The ability to indicate the importance of the decision criteria is a substantial benefit of AHP, and the weights determined by its means are used in multi-criteria decision analyses using other methods.

For the determination of the weights, the ANP method has been also proposed. Relevant applications have been described elsewhere (Lin et al., 2010; Kabak et al., 2012). Chiu et al. (2013) proposed to use the DEMATEL-based ANP method for this purpose.

The DEMATEL method was developed in the 1970s with a view to solving complex problems in the identification of cause-effect relationships (Gabus and Fontela, 1972; Fontela and Gabus, 1974). With time, this method has been well adapted for use in multi-criteria decision making. A description of the DEMATEL method can be found elsewhere (e.g. Dytczak, 2010; Michnik, 2013; Tzeng and Huang, 2011).

Some authors discuss the use of DEMATEL to determine the significance of the criteria (e.g. Shieh et al., 2010; Wu and Tsai, 2011; Hsu et al., 2013). Hsu et al. (2013) described using the DEMATEL approach to recognize influential criteria of carbon management in the green supply chain for improving the overall performance of suppliers. Shieh et al. (2010) applied DEMATEL to hospital management by evaluating the importance of criteria and constructing causal relationships among the criteria. Wu and Tsai (2011) discussed the application of DEMATEL to evaluate the importance of criteria in the auto spare parts industry.

In the DEMATEL method, similarly to the AHP/ANP method, structural relationships occur between the analyzed elements. It is a premise for the use of DEMATEL in the weighting of criteria. Some authors have discussed the use of DEMATEL in the weighting process (e.g. Dalalah et al., 2011; Baykasoglu et al., 2013; Patil and Kant, 2014). In some cases, their approach may lead to incorrect results (this will be explained in section 3). Here we propose a new approach to the calculation of criteria weights using DEMATEL and which is different from the procedures used in the papers above. In the next section, a general description of DEMATEL is presented. The subsequent sections deal with the use of DEMATEL in multi-criteria decision analysis, as well as in calculating criteria weights. Furthermore, using numerical examples, a comparison of weights resulting from DEMATEL and AHP has been conducted.

## 2 Description of the DEMATEL method

As mentioned earlier, the DEMATEL method was elaborated as a procedure for solving problems of identifying cause-and-effect relationships. For modelling problems, DEMATEL uses a direct-influence graph, which expresses the mutual influence of the analysed objects in terms of cause-and-effect relationships (Gabus and Fontela, 1972; Dytczak, 2010; Michnik, 2013; Tzeng and Huang, 2011). Each node of the graph represents an analysed object, whereas an arc between two nodes indicates the direction and intensity of influence relations (Figure 1). The intensity of the influence is defined by values assigned to the given arc. To express the influence of the $i$-th object on the $j$-th object, an $N$-degree scale is used, where: 0 – no influence, 1 – medium influence, …, $N$ – maximum influence. Gabus and Fontela (1972) adopted a 4-degree scale. Currently, the most frequently used are: the original 4-degree scale and a 3-degree scale, but other scales, e.g., a 5-degree scale or even an 8-degree scale are also encountered.

Using the direct influence graph, the direct-influence matrix is created, which is a square matrix whose size is equal to the number of the objects. Its rows correspond to the objects appearing in the comparison as first. The elements on the main diagonal are zeros, while elements $b_{ij}(i \neq j)$ different to zero reflect the impact of the *i*-th object on the *j*-th object:

$$\mathbf{B} = \begin{bmatrix} 0 & b_{1,2} & \dots & b_{1,n} \\ b_{2,1} & 0 & \dots & b_{2,n} \\ \dots & \dots & \dots & \dots \\ b_{n,1} & b_{n,2} & \dots & 0 \end{bmatrix}. \tag{1}$$

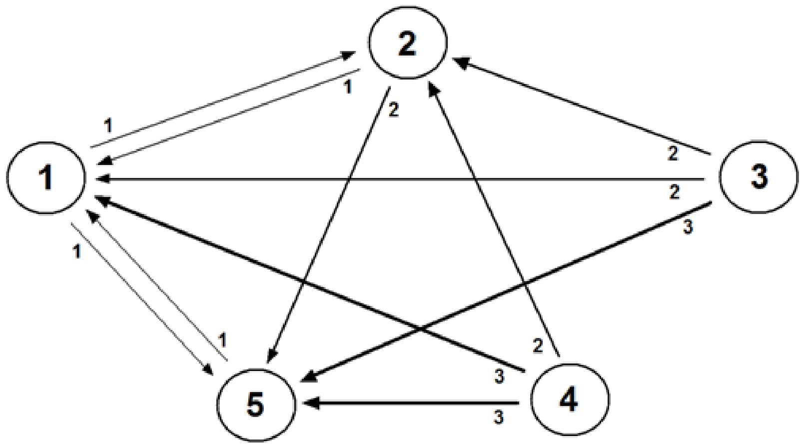


Figure 1. Direct-influence graph in the DEMATEL method

It should be noted that both AHP and DEMATEL are based on the accurate initial matrix, which reflects the relationships between the analysed elements. However, in AHP, the starting point is the pairwise comparison of all elements from each individual level of the structure. As a result, the initial pairwise comparison matrix in the original multiplicative version of AHP does not contain zeros. By contrast, the initial direct influence matrix in DEMATEL does contain zeros. Apart from the main diagonal, zeros can occur also outside the diagonal, if the corresponding objects do not exert sufficient influence on the others.

Matrix (1) is normalised, by dividing each element by the maximum value of the row sum:

$$\hat{\mathbf{B}} = \frac{1}{\max_i \left( \sum_{j=1}^{n} b_{i,j} \right)} \mathbf{B} \tag{2}$$

or by the maximum value of the column sum:

$$\hat{\mathbf{B}} = \frac{1}{\max_j \left( \sum_{i=1}^{n} b_{i,j} \right)} \mathbf{B} \,. \tag{3}$$

The normalisation of matrix **B** can be performed using the greater of these two sums, which is one of the possible ways of normalisation. The direct influence matrix may also require a more complex normalisation to obtain convergent powers of the matrix in Eq. (5). Here, we use the normalisation recommended by the authors of the DEMATEL method.

From the normalised direct-influence matrix $\hat{\mathbf{B}}$ we calculate the total-influence matrix (**T**), which covers direct and indirect influences $\Delta\hat{\mathbf{B}}$:

$$\mathbf{T} = \hat{\mathbf{B}} + \Delta\hat{\mathbf{B}} \,. \tag{4}$$

The total-influence matrix is described by the equation:

$$\mathbf{T} = \hat{\mathbf{B}} + \hat{\mathbf{B}}^2 + \hat{\mathbf{B}}^3 + \ldots = \hat{\mathbf{B}}\left(\mathbf{I} - \hat{\mathbf{B}}\right)^{-1} , \tag{5}$$

where **I** is the $n \times n$ unit matrix.

Matrix **T** allows to express a relation between the considered objects, covering both direct and indirect influences. For this purpose, appropriate indicators are used, defined as importance indicator ($\boldsymbol{t}^{+}$) and relation indicator ($\boldsymbol{t}^{-}$). They are determined using sums and differences of the row and column sums of matrix **T** corresponding to the *i*-th object:

$$t_i^{+} = \sum_{j=1}^{n} t_{i,j} + \sum_{j=1}^{n} t_{j,i} \,, \tag{6}$$

$$t_i^{-} = \sum_{j=1}^{n} t_{i,j} - \sum_{j=1}^{n} t_{j,i} \,. \tag{7}$$

The importance indicator expresses the role of the object in determining the relation structure between the objects, while the relation indicator expresses the general character of the object, understood as the total influence of this object on all the remaining ones. A positive value of the relation indicator confirms that the given object constitutes the cause, whereas a negative value proves the effect character of the object. The absolute value of the indicator defines the intensity of the effect nature of the object.

DEMATEL can be used as a method of multi-criteria decision making, if the analysed objects represent alternative solutions of the decision problem. Suggestions to use DEMATEL in multi-criteria decision making have been proposed and described in numerous papers (e.g. Chen and Tzeng, 2011; Chen et al., 2010; Lee et al., 2013; Lin and Wu, 2008; Liou, 2007; Shen et al., 2011; Tamura and Akazawa, 2005a, 2005b, 2006; Tzeng et al., 2007; Wu and Lee, 2007; Yang and Tzeng, 2011).

## 3 The determination of weights using the DEMATEL method

In the papers Baykasoglu et al. (2013) and Dalalah et al. (2011), the DEMATEL method is used also to determine weights of criteria using the following dependencies:

$$\omega_i = \left(\left(t_i^+\right)^2 + \left(t_i^-\right)^2\right)^{1/2} . \tag{8}$$

The values $\omega_i$ can be normalised as follows:

$$W_i = \frac{\omega_i}{\sum_{i=1}^{n} \omega_i} , \tag{9}$$

where $W_i$ are the final criteria weights to be used in the decision-making process. This is not an accurate approach, since by using the above equations the same weight is assigned to any two criteria $i$ and $j$, $i \neq j$, for which $t_i^+ = t_j^+$ but $t_i^- = \left|t_j^-\right|$ (whereby $t_j^- < 0$).

Here, a different approach is proposed for determining the criteria weights using DEMATEL, which does not have this drawback. We assume that the indicators $t_i^+$ and $t_i^-$ are determined from Eqs. (6) and (7) using the total-influence matrix that results from the direct-influence graph, reflecting the relative importance of the criteria. Since the role and level of the objects' influence are proportional to the value of importance and relation indicators, it is suggested, as one of the possibilities, that the weights be determined as proportional to the average value ($t^{average}$) of the appropriate pair of indicators $t_i^+$ and $t_i^-$ (Kobryń, 2014). From Eqs. (6) and (7), we obtain:

$$t_i^{average} = \frac{1}{2}\left(t_i^+ + t_i^-\right) = \sum_{j=1}^{n} t_{i,j} . \tag{10}$$

To calculate the normalised weights ($\sum w_i = 1$), the following equation can be used:

$$w_i = \frac{t_i^{average}}{\sum_{i=1}^{n} t_i^{average}}. \tag{11}$$

However, it should be noted that if any criterion is totally dominated by other criteria, the corresponding ratings of this criterion resulting from the direct-influence graph are equal to 0. This creates substantial difficulties, since as a result, the corresponding row in the direct-influence matrix consists of zeros only. Therefore, as seen from Eq. (5), the corresponding row of the total-influence matrix **T** will also consist of zeros. From Eqs. (6), (7) and (10), we see that in this case $t_i^{average} = 0$, and therefore – in accordance with Eq. (11) – we have $w_i = 0$. But this would mean that the given criteria exert practically no influence on results of the analysis.

It may be worth mentioning here that a very popular weighting procedure is the AHP method. However, it should be noted that when a given criterion is dominated by another criterion, the calculation procedure of AHP leads to the assignment of a positive and relatively small weight to this criterion (see numerical examples in the next section).

It is significant that all the criteria should have an adequate influence on the final result of the analysis. Criteria whose weights are zeros cannot occur in the set of criteria. Therefore, when comparing criteria and determining their weights using the DEMATEL method, it is necessary to correct the weight values calculated from Eq. (11).

We propose to increase the weights using the same value $\delta$:

$$w_i^{corrected} = w_i + \delta \tag{12}$$

and then to re-normalise them using the following equation:

$$w_i^{normalized} = \frac{w_i^{corrected}}{\sum_{i=1}^{n} w_i^{corrected}}. \tag{13}$$

The key issue is to determine the correction value $\delta$. Obviously, the influence of the correction on the final weights should be examined.

It seems that the final decision should belong to the decision-maker. Since the main goal is to correct the weight whose initial value is zero, the correction value $\delta$ should be as small as possible. The present author suggests setting $\delta \le \Delta$, where $\Delta$ is the smallest non-zero weight of the remaining criteria:

$$\Delta = \min_i w_i \quad \text{if} \quad w_i > 0. \tag{14}$$

## 4 Numerical examples

This section presents numerical examples that illustrate the proposed procedure. In addition, the weights calculated using the DEMATEL method were compared with the weights calculated using the very popular AHP method.

**Example 1 – determining weights of criteria using the DEMATEL method**
Assume that the objects $i = 1, 2, \ldots, 5$ in Figure 1 correspond to the given decision criteria, and that their weights are determined using the suggested procedure. The direct-influence graph from Figure 1 corresponds to the following direct-influence matrix:

$$\mathbf{B} = \begin{bmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 2 \\ 2 & 2 & 0 & 0 & 3 \\ 3 & 2 & 0 & 0 & 3 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix}. \tag{15}$$

Therefore, the following total-influence matrix **T** is obtained from Eq. (5):

$$\mathbf{T} = \begin{bmatrix} 0.036437 & 0.129555 & 0 & 0 & 0.161943 \\ 0.161943 & 0.020243 & 0 & 0 & 0.275304 \\ 0.348178 & 0.293522 & 0 & 0 & 0.491903 \\ 0.477733 & 0.309717 & 0 & 0 & 0.512146 \\ 0.129555 & 0.016194 & 0 & 0 & 0.020243 \end{bmatrix}. \tag{16}$$

According to Eqs. (6), (7), (10) and (11), the relevant weights are obtained from matrix **T** (Table 1).

Table 1: Determination of criteria weights using DEMATEL

| **Criterion** | **Importance ($t_i^+$)** | **Relation ($t_i^-$)** | **Weight ($w_i$)** |
|---|---|---|---|
| 1 | 1.4818 | -0.8259 | 0.097 |
| 2 | 1.2267 | -0.3117 | 0.135 |
| 3 | 1.1336 | 1.1336 | 0.335 |
| 4 | 1.2996 | 1.2996 | 0.384 |
| 5 | 1.6275 | -1.2955 | 0.049 |
| | | Sum of weights = | 1.000 |

**Example 2 – comparison of weights determined using the AHP and DEMATEL methods**

**Case 2.1:** In determining the interdependencies between the criteria, it is important that the relevant ratings be coherent. The coherence of the ratings means that the following conditions are satisfied: $\forall_{i,j,k=1,2,\ldots,m} \quad p_{i,j}\, p_{j,k} = p_{i,k}$, where $p_{i,j}$,

$p_{j,k}$ and $p_{i,k}$ are elements of the pairwise comparison matrix. In practice, those conditions are rarely satisfied by the complete given set of criteria. As it is known, an integral component of the method is the ratings coherence algorithm resulting from the pairwise comparison matrix. There is no such possibility, however, in the DEMATEL method. For that reason, to compare the weights determined using the AHP and DEMATEL methods, we will rely on the ratings assumed for the calculation purposes in the AHP method.

In the case of DEMATEL, the weights are calculated as proposed here, i.e. using Eqs. (10) through (14). Additionally, for comparison, the weights will be calculated using Eqs. (8) and (9).

Assume the following pairwise comparison AHP matrix:

$$\mathbf{P} = \begin{bmatrix} 1 & 9 & 9 & 5 & 3 \\ 1/9 & 1 & 3 & 1/5 & 1/9 \\ 1/9 & 1/3 & 1 & 1/5 & 1/9 \\ 1/5 & 5 & 5 & 1 & 1/3 \\ 1/3 & 9 & 9 & 3 & 1 \end{bmatrix}. \tag{17}$$

The following vector of weights is calculated using AHP:

$$\mathbf{w}^T = \begin{bmatrix} 0.505 & 0.047 & 0.030 & 0.132 & 0.286 \end{bmatrix}. \tag{18}$$

Following consistency check results are obtained for calculations using AHP: $\lambda_{max} = 5.3691$, $CR = 0.083$. The use of the ratings from matrix **P** in DEMATEL requires the agreement of measurement scales used in both methods. Assuming $N = 8$ in DEMATEL, we can use the scales from Table 2 (Dytczak, 2010).

Table 2: Agreement of measurement scales used in AHP and DEMATEL

| **Scale level in AHP** | **Scale level in DEMATEL (*N* = 8)** |
|---|---|
| 1 | 0 |
| 2 | 1 |
| 3 | 2 |
| 4 | 3 |
| 5 | 4 |
| 6 | 5 |
| 7 | 6 |
| 8 | 7 |
| 9 | 8 |

Source: Dytczak (2010).

Additionally, note a lack of feedback for criteria in DEMATEL. For comparison, the following reciprocity rule applies in AHP:

$$p_{j,i} = 1/p_{i,j} \tag{19}$$

If feedback does not occur, as for example between criteria 1 and 2 in Figure 1, the corresponding elements of the direct-influence matrix **B** are zeros. As a result, it can be assumed that matrix **P** in AHP corresponds to the following matrix **B** in DEMATEL:

$$\mathbf{B} = \begin{bmatrix} 0 & 8 & 8 & 4 & 2 \\ 0 & 0 & 2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 4 & 4 & 0 & 0 \\ 0 & 8 & 8 & 2 & 0 \end{bmatrix}. \qquad (20)$$

From matrix **B**, the following total-influence matrix **T** is obtained:

$$\mathbf{T} = \begin{bmatrix} 0 & 0.431255 & 0.470460 & 0.190083 & 0.090909 \\ 0 & 0 & 0.090909 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0.181818 & 0.198347 & 0 & 0 \\ 0 & 0.380165 & 0.414726 & 0.090909 & 0 \end{bmatrix}. \qquad (21)$$

Since criterion 3 is dominated by the remaining criteria (the third row of **B** is filled with zeros), the third row of **T** is also filled with zeros. Therefore, the weight of the third criterion determined from Eq. (10) is $w_3 = 0$. For that reason, a correction of all weights is necessary, as shown in Table 3 (since $\Delta$ is small, we set $\delta = \Delta = 0.0358$).

We can see that the weights determined using the two methods usually exhibit high compatibility; the greatest difference of their values occurs for criterion 3 and is equal to $\Delta w = 0.08$.

Table 3: Determining weights of criteria using DEMATEL with correction (case 2.1)

| **Criterion** | **Importance** $(t_i^+)$ | **Relation** $(t_i^-)$ | **Weight** $(w_i)$ | **Corrected weight** $(w_i^{corrected})$ | **Normalized weight** $(w_i^{normalizaed})$ |
|---|---|---|---|---|---|
| 1 | 1.1827 | 1.1827 | 0.4657 | 0.5015 | 0.425 |
| 2 | 1.0841 | -0.9023 | 0.0358 | 0.0716 | 0.061 |
| 3 | 1.1744 | -1.1744 | 0.0000 | 0.0358 | 0.031 |
| 4 | 0.6612 | 0.0992 | 0.1497 | 0.1855 | 0.157 |
| 5 | 0.9767 | 0.7949 | 0.3488 | 0.3846 | 0.326 |
| | | Sum = | 1.0000 | 1.1790 | 1.000 |

**Case 2.2:** Analogous calculations will now be conducted for a different set of initial data. We assume now that the following pairwise comparison matrix is used in the AHP method:

$$\mathbf{P} = \begin{bmatrix} 1 & 1/9 & 1/9 & 1/7 & 1/5 \\ 9 & 1 & 2 & 5 & 5 \\ 9 & 1/2 & 1 & 2 & 3 \\ 7 & 1/5 & 1/2 & 1 & 1/2 \\ 5 & 1/5 & 1/3 & 2 & 1 \end{bmatrix}. \tag{22}$$

From matrix **P**, the following weight vector is obtained:

$$\mathbf{w}^T = \begin{bmatrix} 0.029 & 0.468 & 0.260 & 0.114 & 0.129 \end{bmatrix}. \tag{23}$$

Following consistency check results are obtained for calculations using the AHP method: $\lambda_{max} = 5.2743$, $CR = 0.062$.

Matrix **P** in (22) corresponds in the DEMATEL method to the following matrix **B**:

$$\mathbf{B} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 8 & 0 & 1 & 4 & 4 \\ 8 & 0 & 0 & 1 & 2 \\ 6 & 0 & 0 & 0 & 0 \\ 4 & 0 & 0 & 1 & 0 \end{bmatrix}. \tag{24}$$

We obtain the following total-influence matrix **T**:

$$\mathbf{T} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0.644556 & 0 & 0.058824 & 0.253002 & 0.242215 \\ 0.521474 & 0 & 0 & 0.065744 & 0.117647 \\ 0.352941 & 0 & 0 & 0 & 0 \\ 0.256055 & 0 & 0 & 0.058824 & 0 \end{bmatrix}. \tag{25}$$

In this case, criterion 1 is dominated by the remaining criteria (the first rows of **B** and **T** consist of zeros). Consequently, the weight of the first criterion ($w_1$) determined from Eq. (9) is equal to 0 (Table 4). It is therefore necessary to correct all weights. Since $\Delta > 0.1$, we set $\delta = 0.5\,\Delta = 0.0612$.

Table 4: Determining weights of criteria using DEMATEL with correction (case 2.2)

| **Criterion** | **Importance** ($t_i^+$) | **Relation** ($t_i^-$) | **Weight** ($w_i$) | **Corrected weight** ($w_i^{corrected}$) | **Normalized weight** ($w_i^{normalizaed}$) |
|---|---|---|---|---|---|
| 1 | 1.7750 | -1.7750 | 0.0000 | 0.0612 | 0.047 |
| 2 | 1.1986 | 1.1986 | 0.4661 | 0.5274 | 0.404 |
| 3 | 0.7637 | 0.6460 | 0.2741 | 0.3354 | 0.257 |
| 4 | 0.7305 | -0.0246 | 0.1373 | 0.1985 | 0.152 |
| 5 | 0.6747 | -0.0450 | 0.1225 | 0.1837 | 0.140 |
| | | Sum = | 1.0000 | 1.3062 | 1.000 |

Also in this case, the weights obtained by the two methods exhibit high compatibility (Table 5). As can be seen, the greatest difference between weight values occurs for criterion 2 ($\Delta w$ = 0.064) and is even smaller than in case 2.1.

Table 5: The weights obtained by AHP and DEMATEL

| Case | Criterion | Weights by AHP | Weights by DEMATEL | |
|---|---|---|---|---|
| | | | approach outlined in the papers Baykasoglu et al., (2013); Dalalah et al. (2011) | proposed approach |
| 2.1 | 1 | 0.505 | 0.251 | 0.425 |
| | 2 | 0.047 | 0.211 | 0.061 |
| | 3 | 0.030 | 0.249 | 0.031 |
| | 4 | 0.132 | 0.100 | 0.157 |
| | 5 | 0.286 | 0.189 | 0.326 |
| | | | | |
| 2.2 | 1 | 0.029 | 0.380 | 0.047 |
| | 2 | 0.468 | 0.256 | 0.404 |
| | 3 | 0.260 | 0.151 | 0.257 |
| | 4 | 0.114 | 0.111 | 0.152 |
| | 5 | 0.129 | 0.102 | 0.140 |

Weights obtained using the proposed approach have been compared also to those obtained using the DEMATEL method as presented in other papers (Baykasoglu et al., 2013; Dalalah et al., 2011). Compared to them, the proposed procedure results in a much higher compatibility of weights with the results obtained by the AHP method.

## 5 Conclusions

Various methods for obtaining criteria weights are known, such as: the entropy method, the Simos method, the AHP or ANP method, the SWARA method, and many others.

Some authors propose to use for this purpose also the DEMATEL method. This is a popular method, which enables an analysis of cause-and-effect relationships. The potential of this method has also been noted in the context of determining weights of criteria (e.g. Baykasoglu et al., 2013; Dalalah et al., 2011; Hsu et al., 2013; Patil and Kant, 2014; Shieh et al., 2010; Wu and Tsai, 2011). Some of the procedures proposed there, however, have certain drawbacks.

In this paper, a new approach for determining weights of criteria using the DEMATEL method has been presented and verified using numerical examples. Moreover, the obtained weights have been compared to those obtained using other methods, namely AHP and DEMATEL, but following an approach presented elsewhere in the literature (e.g. Baykasoglu et al., 2013; Dalalah et al., 2011). The numerical examples presented here show that the weights determined using the proposed approach exhibit high compatibility with weights determined using the commonly used AHP method.

An implementation of the proposed approach to selected multiple criteria problems may be the next stage of our research. It is a useful method which can be applied to various problems.

## References

De Almeida et al. (2016), *A New Method for Elicitation of Criteria Weights in Additive Models: Flexible and Interactive Tradeoff*, European Journal of Operational Research, 250, 179-191.

Barron F.H., Barret B.E. (1996), *Decision Quality Using Ranked Attribute Weights*, Management Science, 42, 1515-1523.

Baykasoglu A., Kaplanoglu V., Durmusoglu Z.D.U., Sahin C. (2013), *Integrating Fuzzy DEMATEL and Fuzzy Hierarchical TOPSIS Methods for Truck Selection*, Expert Systems with Applications, 40, 899-907.

Chen C.H., Tzeng G.H. (2011), *Creating the Aspired Intelligent Assessment Systems for Teaching Materials*, Expert Systems with Applications, 38, 12168-12179.

Chen Y.C., Lien H.P., Tzeng G.H (2010), *Measures and Evaluation for Environment Watershed Plans Using a Novel Hybrid MCDM Model*, Expert Systems and Applications, 37, 926-938.

Chiu W.Y., Tzeng G.H., Li H.L. (2013), *A New Hybrid MCDM Model Combining DANP with VIKOR to Improve e-store Business*, Knowledge-Based Systems, 37, 48-61.

Dalalah D., Hajaneh M., Batieha F. (2011), *A Fuzzy Multi-criteria Decision Making Model for Supplier Selection*, Expert Systems with Applications, 38, 8384-8391.

Deng H., Yeh C.H., Willis R.J. (2000), *Inter-company Comparison Using Modified TOPSIS with Objective Weights*, Computers & Operations Research, 27, 963-973.

Dytczak M. (2010), *Wybrane metody rozwiązywania wielokryterialnych problemów decyzyjnych w budownictwie*, Wydawnictwa Politechniki Opolskiej, Opole.

Edwards W., Barron F.H. (1994), *SMARTS and SMARTER: Improved Simple Methods for Multi-attribute Utility Measurement*, Organizational Behavior and Human Decision Processes, 60, 306-325.

Figueira J., Roy B. (2002), *Determining the Weights of Criteria in the ELECTRE type Methods with a Revised Simos' Procedure*, European Journal of Operational Research, 139, 317-326.

Fontela E., Gabus A. (1974), *DEMATEL, Innovative Methods*, Rep. No. 2, Structural Analysis of the World Problematique (Methods), Battelle Institute, Geneva Research Center, Geneva.

Gabus A., Fontela E. (1972), *World Problems an Invitation to Further thought within the Framework of DEMATEL*, Batelle Institute, Geneva Research Center, Geneva.

Hsu C.W., Kuo T.C., Chen S.H., Hu A.H. (2013), *Using DEMATEL to Develop a Carbon Management Model of Supplier Selection in Green Supply Chain Management*, Journal of Cleaner Production, 56, 164-172.

Ignasiak E., red. (2001), *Badania operacyjne*, PWE, Warszawa.

Kabak M., Burmaoglu S., Kazancoglu Y. (2012), *A Fuzzy Hybrid MCDM Approach for Professional Selection*, Expert Systems with Applications, 39, 3516-3525.

Keršuliene V., Zavadskas E.K., Turskis Z. (2010), *Selection of Rational Dispute Resolution Method by Applying New Step-wise Weight Assessment Ratio Analysis (SWARA)*, Journal of Business Economics and Management, 11(2), 243-258.

Kobryń A. (2014), *Wielokryterialne wspomaganie decyzji w gospodarowaniu przestrzenią*, Wydawnictwo DIFIN, Warszawa.

Lee H.S., Tzeng G.H., Yeih W., Wang Y.J., Yang S.C. (2013), *Revised DEMATEL: Resolving the Infeasibility of DEMATEL*, Applied Mathematical Modelling, 37, 6746-6757.

Lin C.J., Wu W.W. (2008), *A Causal Analytical Method for Group Decision-making under Fuzzy Environment*, Expert Systems and Applications, 34, 205-213.

Lin Y.T., Lin C.L., Yu H.C., Tzeng G.H. (2010), *A Novel Hybrid MDCM Approach for Outsourcing Vendor Selection: A Case Study for a Semiconductor Company in Taiwan*, Expert Systems and Applications, 37, 4796-4804.

Liou Y. (2007), *Water Quality Analysis Model Based on DEMATEL and ANP*, 22nd European Conference on Operational Research EURO XII. Book of Abstracts, Praha.

Michnik J. (2013), *Wielokryterialne metody wspomagania decyzji w procesie innowacji*, Prace Naukowe Uniwersytetu Ekonomicznego, Katowice.

Patil S.K., Kant R. (2014), *A Hybrid Approach Based on Fuzzy DEMATEL and FMCDM to Predict Success of Knowledge Management Adoption in Supply Chain*, Applied Soft Computing, 18, 126-135.

Roy R., Mousseau V. (1996), *A Theoretical Framework for Analyzing the Notion of Relative Importance of Criteria*, Journal of Multi-Criteria Decision Analysis, 5, 145-159.

Saaty T.L. (1980), *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, McGraw-Hill, New York.

Shannon C.E., Weaver W. (1963), *The Mathematical Theory of Communication*, University of Illinois Press, Urbana and Chicago.

Shen Y.C., Lin G.T., Tzeng G.H. (2011), *Combined DEMATEL Techniques with Novel MCDM for the Organic Light Emitting Diode Technology Selection*, Expert Systems with Applications, 38, 1468-1481.

Shieh J.I., Wu H.H., Huang K.H. (2010), *A DEMATEL Method in Identifying Key Success Factors of Hospital Service Quality*, Knowledge-Based Systems, 23, 277-282.

Simos J. (1990), *L'évaluation environnementale*: *Un processus cognitive négocié, Thèse de doctorat*, DGF-EPFL, Lausanne.

Solymosi T., Dombi J. (1986), *A Method for Determining the Weights of Criteria: The Centralized Weights*, European Journal of Operational Research, 26, 35-41.

Tamura H., Akazawa K. (2005a), *Structural Modeling and Systems Analysis of Uneasy Factors for Realizing Safe, Secure and Reliable Society*, Journal of Telecommunications and Information Technology, 3, 64-72.

Tamura H., Akazawa K. (2005b), *Stochastic DEMATEL for Structural Modeling of a Complex Problematique for Realizing Safe, Secure and Reliable Society*, Journal of Telecommunications and Information Technology, 4, 139-146.

Tamura H., Akazawa K. (2006), *Decision Support for Extracting and Dissolving Consumers' Uneasiness over Foods Using Stochastic DEMATEL*, Journal of Telecommunications and Information Technology, 4, 91-95.

Tzeng G.H., Chiang C.H., Li C.W. (2007), *Evaluating Intertwined Effects in e-learning Programs: A Novel Hybrid MCDM Model Based on Factor Analysis and DEMATEL*, Expert Systems with Applications, 32(4), 1028-1044.

Tzeng G.H., Huang J.J. (2011), *Multiple Attribute Decision Making: Methods and Applications*, CRC Press, Taylor & Francis Group.

Wang J., Zionts S. (2006), *Random-weight Generation in Multiple Criteria Decision Models*, MCDM' 2006, Chania, Greece, June 19-23.

Wu W.W., Lee Y.T. (2007), *Developing Global Managers' Competencies Using the Fuzzy DEMATEL Method*, Expert Systems with Applications, 32, 499-507.

Wu H.H, Tsai Y.N. (2011), *A DEMATEL Method to Evaluate the Causal Relations among the Criteria in Auto Spare Parts Industry*, Applied Mathematics and Computation, 218, 2334-2342.

Yang J., Tzeng G.H. (2011), *An Integrated MCDM Technique Combined with DEMATEL for a Novel Cluster-weighted with ANP Method*, Expert Systems and Applications, 38, 1417-1424.

Zolfani S.H., Aghdaie M.H., Derakthi A., Zavadskas E.K., Varzandeh M.H.M. (2013), *Decision Making on Business Issues with Foresight Perspective: An Application of New Hybrid MCDM Model in Shopping Mall Locating*, Expert Systems and Applications, 40, 7111-7121.