GOOD NEWS FOR DEMATEL USERS: THE ORIGINAL POTENTIAL OF THE METHOD IS STILL AWAITING FULL EXPLOITATION

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Abstract. DEMATEL technique is almost 50 years old. A long history of its application to solve diverse problems from different fields has provided diverse improvements to the technique to make it even more powerful. It nevertheless seems that some original merits of the technique were accidentally lost, as well. The merits proved to be very useful for a complex and comprehensive research made by DEMATEL inventors. So, it seems that they could also prove useful for contemporary researchers. This why an effort is made in the paper to recall and describe these merits and assess their usefulness for supporting a comprehensive decision analysis today.

Keywords: DEMATEL, original, potential, application, decision, analysis, support.

JEL Classification: C65.

1. Introduction

DEMATEL technique has been developed rather a long time ago. The original purpose of the technique was the identification of the structure of contemporary world’s problems. The technique was invented during actual realization of a research project at the Batelle Memorial Institute, Geneva, Switzerland in the early 1970s by the team led by two researchers, namely Emilio Fontela and André Gabus. The technique has been invented particularly for the implementation research project was called DECision MAKing Trial and Evaluation Laboratory of the Science and Human Affairs Program of the Batelle Memorial Institute (Fontela & Gabus, 1973).

DEMATEL technique became particularly popular in the beginning of the 21st century (see: Figure 1). It has been utilized since then for solving numerous problems in diverse areas (see: Figure 2), and diverse purposes (Sheng-Li et al., 2018; Kawata, 1981; Furumoto et al., 1998; Hori & Shimizu, 1999; Ren et al., 2001; Fukushima & Narita, 2002; Tamura & Akazawa, 2005; Chiu et al., 2006; Wu & Lee, 2007; Liou et al., 2008; Dytczak & Ginda, 2009, 2013; Lee et al., 2010; Jerry Ho et al., 2011; Wu et al., 2012; Lee, 2013; Tan & Kuo, 2014; Qu et al., 2015; Lin et al., 2016; Zhou et al., 2017; Chen et al., 2018; Torbacki & Kijewska, 2019; Jayakrishna et al., 2020). The main reason for the great popularity of the technique results from its capability to provide means for the effective identification of cause-effect chains despite the availability of rather scarce information about influence of objects that comprise a considered system.

Figure 1. Yearly rate of DEMATEL-related publications (source: http://www.scopus.com)

Typical DEMATEL application exploits the basic procedure which consists of the following steps. The first step deals with the definition of a structure of direct influence of components of a given system on each other. Note that actual notion of direct influence results from actual needs of analysis, namely: character of considered system, its components and interactions between them, etc. Levels of an ordinal scale are utilized to express direct influence of system components. The scale always consists of level 0, which expresses a lack of direct influence, and level N, which pertains to the extreme possible direct influence. The intermediate scale lev-
nels, from 1 to \(N-1\), denote increasing direct influence intensity. Original DEMATEL scale consists of 5 levels which are expressed by consecutive integers: 0, 1, 2, 3, and \(N = 4\). Note that the assessment of direct influence intensity may be provided by \(K\) different experts. Each expert delivers a set of assessments which corresponds with his view of a structure of direct influence. The structure covers direction and intensity of direct influence of \(n\) components of a considered system on each other. The consecutive system components may be associated with subsequent rows and columns of a quadratic \(n \times n\) matrix of direct influence \(\mathbf{X}^{(k)}\). The element \(x_{ij}^{(k)}\) of the matrix corresponds with possible direct influence of the \(i\)-th consecutive system component on the \(j\)-th consecutive system component, according to the \(k\)-th consecutive expert:

\[
\forall_{k=1..K} \mathbf{X}^{(k)} = \left[ x_{ij}^{(k)} \right]_{na}.
\]  

Note that a digraph of direct influence, which corresponds with matrix (1) may be also applied to express and visualize structure of direct influence. Nodes of the digraph correspond to system components while weighted arcs express possible direct impact of the components on the remaining system components.

The second step of the procedure results in average direct influence structure. The structure is expressed by a quadratic \(n \times n\) matrix \(\mathbf{X}^*\):

\[
\mathbf{X}^* = \frac{1}{K} \sum_{k=1}^{K} \mathbf{X}^{(k)}. \tag{2}
\]

The third step is devoted to deriving adequate form \(\mathbf{X}\) of matrix (2) that satisfies the following condition:

\[
\mathbf{X}^* \to \mathbf{X}: \lim_{m \to +\infty} \mathbf{X}^m = \mathbf{0}_{n \times n}. \tag{3}
\]

The structure of total influence covers both direct \(\mathbf{X}\) and indirect influence \(\Delta \mathbf{X}\) of system components. It is represented by a quadratic \(n \times n\) matrix of total influence \(\mathbf{T}\):

\[
\mathbf{T} = \mathbf{X} + \Delta \mathbf{X}. \tag{4}
\]

The adequate form of direct influence matrix \(\mathbf{X}\) (3) allows to derive structure of total influence thanks to the following formula:

\[
\mathbf{T} = \mathbf{X} \left( \mathbf{I} - \mathbf{X} \right)^{-1}, \tag{5}
\]

where \(\mathbf{I}\) denotes an \(n \times n\) identity matrix.

The element \(t_{ij}\) of the matrix expresses total influence of the \(i\)-th consecutive system component on the \(j\)-th consecutive system component. Note that a structure of total influence may be also expressed by a digraph of total influence which corresponds with matrix \(\mathbf{T}\) contents.

Matrix \(\mathbf{T}\) makes it possible to compute two indices (6, 7) for the \(i\)-th consecutive system component:

\[
\forall_{i=1..n} s_i^+ = \sum_{j=1}^{n} \left( t_{ij} + t_{ji} \right), \tag{6}
\]

\[
\forall_{i=1..n} s_i^- = \sum_{j=1}^{n} \left( t_{ij} - t_{ji} \right). \tag{7}
\]

The first index (6) is called the prominence. It is used to express overall significance of the \(i\)-th consecutive system component. Note that it is based on the sum of matrix \(\mathbf{T}\) elements in the \(i\)-th consecutive row and the \(i\)-th consecutive column. Note that the higher value of \(s_i^+\) is, the more significant the \(i\)-th consecutive system component is. The second index (7) is called the relation. It is used to express role of the \(i\)-th consecutive system component. Note that the higher the positive value of the index is, the more causal the \(i\)-th consecutive system element is. On the other hand, the lower the negative value of the relation is, the more certain effect the \(i\)-th consecutive system component is.

It proves out, however, that the technique actually provides more interesting features than just the effective identification of cause-effect chains. This is because original reports about the technique (Fontela & Gabus, 1973; Fontela, 1974; Gabus, 1974; Fontela, & Gabus, 1975; Gabus & Fontela, 1975; Gabus & Fontela, 1976), which have been provided by DEMATEL inventors, namely: Emilio Fontela and André Gabus, indicated many more interesting features of the technique which seem not to be recognized by contemporary technique users. It seems that this is mainly due to actual unavailability of original information about the technique. Indeed, several orig-
inal reports became available to Internet users in early years of the 21st century when the general interest in the technique was only starting to grow, and it left the majority, particularly new, DEMATEL users unaware of some interesting features of the technique. The presentation of forgotten ideas behind the original technique proposal becomes purposeful, therefore. This is why they are presented in the paper.

The paper is structured as follows. Results of original DEMATEL application are used in the paper to illustrate its forgotten features. This is why a background of original version of technique development is presented in the second section. The third section is devoted to the forgotten features themselves. Final conclusions with regard to the possible contemporary usefulness of the features are drawn in the final section.

2. DEMATEL origin background

A block scheme of complete procedure of original DEMATEL is presented in Figure 3. It is obvious that there are three fundamental differences between original proposal of Fontela and Gabus as well as the commonly known and used form of the technique, which was discussed in section 1.

The first fundamental difference deals with the possibility of analysis of individual direct influence structures provided by distinct experts \( X^{(k)} \) and average direct influence structure \( X^* \). The second fundamental difference pertains to the analysis of indirect influence structure \( \Delta X \) while the last fundamental difference is related to enhancements of total influence structure analysis.

A system which was originally analyzed during the implementation of original DEMATEL project by Fontela and Gabus (1973) is used in a paper to present original features of the technique. The system dealt with 48 contemporary world’s problems of the early 1970s. The problems covered both global world issues as well as regional issues. They were divided in 14 thematic groups A-N which covered (note the original spelling) (Gabus & Fontela, 1976):

- theme A – obstacles to world organization: inadequacy of the institutional organizations of international society \((i = 1)\), the difficulty experienced by major powers in defining their interests and responsibility \((i = 2)\), the arms race \((i = 3)\), and inadequate regulation of use of the sea \((i = 4)\),
- theme B – infringement of the rights of nations: interference by foreign powers \((i = 5)\), interference by multinational companies \((i = 6)\), and non-completion of decolonisation \((i = 7)\),
- theme C – ineffectiveness of institutions: inability of institutions to adapt to external change \((i = 8)\), political instability, particularly in the less-developed countries – LDCs \((i = 9)\), insufficient personal involvement in political and economic life \((i = 10)\),
- theme D – difficulties in improving the standard of living in rapidly growing population: disproportion between active and inactive population \((i = 11)\), maladaptation of urban concentration to individual and collective needs \((i = 12)\), poor use of available land \((i = 13)\),
- theme E – the crisis of advanced industrial societies: physical and mental illnesses characteristics of advanced industrial civilisation \((i = 14)\), loss of the sense of personal security \((i = 15)\), obstacles to fulfillment of of non-material aspirations \((i = 16)\),
- theme F – social discrimination: racial discrimination \((i = 17)\), recurring threats to the existence of minorities \((i = 18)\), social discrimination based on sex \((i = 19)\),
- theme G – the use of violence: physical violence in political and social conflicts \((i = 20)\), infringements of fundamental per-

\[ \Delta X = \sum_{i=1}^{20} \sum_{j=1}^{20} \Delta X_{ij} \]

\[ X^* = \left( \sum_{i=1}^{20} X_i \right) / 20 \]

\[ T = \left( \sum_{i=1}^{20} T_i \right) / 20 \]

\[ T' = \left( \sum_{i=1}^{20} T'_i \right) / 20 \]

\[ T'' = \left( \sum_{i=1}^{20} T''_i \right) / 20 \]

\[ \Delta X = X^* - T' - T'' \]

\[ X^{(k)} = X^* - X^{(k)} - T' - T'' \]

\[ X^{(k)} = X^* - X^{(k)} - T' - T'' \]

\[ T = \left( \sum_{i=1}^{20} T_i \right) / 20 \]

\[ T' = \left( \sum_{i=1}^{20} T'_i \right) / 20 \]

\[ T'' = \left( \sum_{i=1}^{20} T''_i \right) / 20 \]

\[ \Delta X = X^* - T' - T'' \]

\[ X^{(k)} = X^* - X^{(k)} - T' - T'' \]

\[ X^{(k)} = X^* - X^{(k)} - T' - T'' \]

\[ \Delta X = X^* - T' - T'' \]

\[ X^{(k)} = X^* - X^{(k)} - T' - T'' \]
sonal freedoms \((i = 21\) ), increase in crimi-
nality and delinquency \((i = 22\) ), hijacking
and sabotage of aircraft \((i = 23\) ),
- theme H – shortcomings in education and
communication: communication diffi-
culties due to complexity and multiplicity of
jargon and languages \((i = 24\) ), intensifica-
tion of political, economic and cultural
propaganda in association with the de-
velopment of mass media \((i = 25\) ), insufficient
education of children and adults for active
life \((i = 26\) ),
- theme I – the weakening of human motiva-
tions: weakening of collective convictions
(social, religious, etc.) \((i = 27\) ), diffi-
culties of social advancement \((i = 28\) ),
acute disparities between living conditions
and aspirations \((i = 29\) ), production, traffic
and use of drugs \((i = 30\) ),
- theme J – degradation and disfigurement
of the environment: lasting damage to vital
properties of water \((i = 31\) ), damage (in-
cluding noise) to the properties of atmos-
phere \((i = 32\) ), damage to vital properties
of the soil \((i = 33\) ), disfigurement of envi-
ronment: destruction of cultural monu-
ments, natural beauties, etc. \((i = 34\) ), at-
tacks on man’s genetic heritage \((i = 35\) ),
- theme K – shortcomings in production and
technology: wastage and underemploy-
ment of human resources \((i = 36\) ), funda-
mental waste of material and financial re-
sources \((i = 37\) ), exhaustion of non-
renewable mineral and energy reserves
\((i = 38\) ), inadequate bcontrol of technolog-
ical development \((i = 39\) ), and insufficient
efforts to anticipate the exhaustion of en-
ergy reserve and to produce less pollutant
energy \((i = 40\) ),
- theme L – monetary instability: difficulty
in checking inflation \((i = 41\) ) and crises in
the international monetary system \((i = 42\) ),
- theme M – obstacles to international eco-
nomic relations: lack of capital for aid to
LDCs \((i = 43\) ), low and fluctuating prices of
exports from LDCs \((i = 44\) ), and chang-
es in the flow of international trade due to
establishment of preferential areas \((i = 45\) ),
- theme N – failure to satify basic needs of
the LDCs: undernutrition and malnutrition
in the LDCs \((i = 46\) ), endemic and epidem-
ic disease in the LDCs \((i = 47\) ), and hous-
ing shortages and deficiencies in LDCs
\((i = 48\) ).

A survey research was applied to gain opinions
of influential persons who represented different con-
tinents, countries, professions and positions (Gabus,
1974) – see: Table 1 and Table 2 with this regard.
The survey research dealt with gessions about direct
influence of problems on each other. The respondents
of the survey were provided with feedback about con-
sequences of their own opinions to facilitate re-
thining their opinions. A total of \(K = 32\) complete
direct problem influence structures were obtained
from the respondents. These structures were finally
processed by means of original DEMATEL tech-
nique.

Table 1. Respondents’ characteristics (source: Gabus &
Fontela, 1976)

<table>
<thead>
<tr>
<th>Function</th>
<th>Codes</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>003, 006, 111, 112, 132</td>
<td>5</td>
</tr>
<tr>
<td>Prime Minister’s delegates / advisors</td>
<td>108, 126, 128</td>
<td>3</td>
</tr>
<tr>
<td>Ministers</td>
<td>110, 135</td>
<td>21</td>
</tr>
<tr>
<td>High official in public administration</td>
<td>117</td>
<td>1</td>
</tr>
<tr>
<td>High official in international organisation</td>
<td>123, 124</td>
<td>2</td>
</tr>
<tr>
<td>Opinion makers / business</td>
<td>133, 134</td>
<td>2</td>
</tr>
<tr>
<td>Trade union leaders</td>
<td>004, 119</td>
<td>2</td>
</tr>
<tr>
<td>Political party representatives</td>
<td>107, 113</td>
<td>2</td>
</tr>
<tr>
<td>Senators</td>
<td>116, 122, 125, 129</td>
<td>4</td>
</tr>
<tr>
<td>Corporate directors</td>
<td>101, 105, 118</td>
<td>3</td>
</tr>
<tr>
<td>University professors</td>
<td>005, 106, 121</td>
<td>3</td>
</tr>
<tr>
<td>Scientific researchers</td>
<td>007, 104, 127</td>
<td>3</td>
</tr>
</tbody>
</table>

3. Less known features of original DEMATEL

3.1. Extra analysis of direct influence

Fontela (1974) proposed several enhancements to
the analysis of direct problem influence. The first
one pertains to the identification of general influen-
tial and consequent character of a distinct problem.
The application of adequate row-wise \((8)\) and col-
umn-wise \((9)\) sum of average direct influence matrix
\(X^*\) was proposed with this regard to measure direct
impact of the i-th consecutive problem on the re-
mainning problems and to measure direct impact of
the remaining problems on the problem, respective-
ly:
average direct impact lower than 2.0 when presenting structure of direct influence shown in Figure 4.

Table 3. Sample results of general problem perception analysis (source: Gabus & Fontela, 1976)

<table>
<thead>
<tr>
<th>Rank</th>
<th>i</th>
<th>Influencer</th>
<th>j</th>
<th>Influenced</th>
<th>$x_{ij}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41</td>
<td>Inflation</td>
<td>42</td>
<td>Monetary system</td>
<td>3.312</td>
</tr>
<tr>
<td>2</td>
<td>43</td>
<td>Insufficient capital</td>
<td>36</td>
<td>HR waste</td>
<td>2.969</td>
</tr>
<tr>
<td>3</td>
<td>46</td>
<td>Insufficient nutrition</td>
<td>47</td>
<td>High prevalence</td>
<td>2.937</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>Civilization diseases</td>
<td>15</td>
<td>No sense of security</td>
<td>2.781</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>Racism</td>
<td>18</td>
<td>Minority situation</td>
<td>2.750</td>
</tr>
</tbody>
</table>

Figure 4. Sample results of original DEMATEL research project (source: Gabus & Fontela, 1976)

The third original DEMATEL proposal dealt with the counting of occurrences of concrete direct influence intensity cases appearing in direct influence structures $X^{(o)}$. The application of distinct matrices $M_o$ was suggested with this regard, where parameter $o$ corresponds with a distinct direct influence level ($o = 0...N$). Element in the i-th consecutive row and the j-th consecutive column of matrix $M_o$ was thus equal to the number of experts who assessed direct impact of the i-th consecutive problem on the j-th consecutive problem as $o$, at least:

$$\forall_{i=1...n} \forall_{j=1...n} x^o_{ij} \geq o.$$  (12)

Note that the number of the matrices is equal to number of direct influence scale levels. Thus, in the case of original DEMATEL application, 5 distinct matrices were used. The matrices were also used to identify the cases of the direct impacts, amongst direct influence structures provided by distinct ep-
erts, which had the same direction and intensity. It is also obvious that individual rows and columns of matrices $\mathbf{M}_0$ refer to the causal and consequent character of individual problems, respectively. This is why the analysis of content of individual rows and columns of the matrices would allow to indicate leading problems in terms of causality or effect, too.

Original DEMATEL also provided means for the identification of direct influence feedback between problems. The application of a quadratic $n$ by $n$ binary matrix $\mathbf{E}$ (13) was proposed in this regard. The elements of the matrix made it possible to indicate the fact of the existence ($e_{ij} = 1$) or a lack ($e_{ij} = 0$) of direct impact of the $i$-th consecutive problem on the $j$-th consecutive problem:

$$
\forall_{i,j=1,..,n} e_{ij} = \begin{cases} 
1 & \text{for } x_{ij} > 0, \\
0 & \text{otherwise.} 
\end{cases} 
$$

(13)

The matrix was then used to obtain another quadratic $n$ by $n$ matrix $\mathbf{F}$:

$$
\mathbf{F} = \mathbf{E} + \mathbf{E}^T,
$$

(14)

whose elements are capable of indicating the following cases for the pair of the $i$-th consecutive problem and the $j$-th consecutive problem:

- a lack of direct impact of any problem ($f_{ij} = 0$),
- a direct impact of only one of the problems on another one ($f_{ij} = 1$),
- a feedback of direct impact ($f_{ij} = 1$).

Fontela and Gabus (1975) also proposed to use information about direct influence of problems to analyse similarity of direct structures $\mathbf{X}^{(k)}$ provided by distinct experts and difference between them. A special metric $d_{kl}^*$ was applied with this regard. The metric made use of a notion of a distance in $n$-dimensional space of problems between qualitative images of direct influence structures provided by the $k$-th consecutive expert and the $l$-consecutive expert. A quadratic $n$ by $n$ binary matrix $\mathbf{D}^{(k)}$ (15) was applied to express qualitative character of direct influence structure $\mathbf{X}^{(k)}$ provided by the $k$-th consecutive expert:

$$
\forall_{k,l=1,..,K} \forall_{i,j=1,..,n} d_{ij}^{(k)} = \begin{cases} 
1 & \text{for } x_{ij}^{(k)} > 0, \\
0 & \text{otherwise.} 
\end{cases} 
$$

(15)

The elements of the matrix show whether the expert recognizess the case of direct impact of the $i$-th consecutive problem on the $j$-th consecutive problem ($d_{ij}^{(k)} = 1$) or not ($d_{ij}^{(k)} = 0$).

Metric $d_{kl}^*$ could be then defined as follows:

$$
\forall_{k,l=1,..,K} d_{kl}^* = \frac{\sum_{i=1}^n \sum_{j=1}^n (d_{ij}^{(k)} - d_{ij}^{(l)})}{n^2}.
$$

(16)

A lack of any difference between expert opinions on a qualitative character of direct influence structure would correspond to $d_{kl}^* = 0$, whereas value of $d_{kl}^* = 0$ close to 1 would mean that experts differ in opinions about direction of direct problem impact a lot.

It was obvious that $d_{kl}^* = 0$ could be treated as means for expressing dissimilarity of expert opinions about qualitative character of direct influence structure. The complement of this metric was proposed, therefore, to be able to express similarity of expert opinions in a direct way:

$$
\forall_{k,l=1,..,K} p_{kl}^* = 1 - d_{kl}^*.
$$

(17)

The application of complement (17) allowed to denote a lack of any difference between expert opinions by means of $p_{kl}^* = 1$, and total dissimilarity of the opinions by value of $p_{kl}^*$ close to 1. Note that in the case of original DEMATEL project implementation, the application of metric $p_{kl}^*$ resulted in the indication of the most compatible experts 107 and 122, for whom the following metric value was registered: $p_{kl}^* = 0.972$.

Another original DEMATEL idea was related to the application of metric $d_{kl}^*$ to create a distance matrix $\mathbf{D}$ which aggregated information about qualitative difference in direct influence structures provided by experts. A concept of average distance was finally applied to define elements of the matrix:

$$
\forall_{k,l=1,..,K} \tilde{d}_{kl} = \sqrt{d_{kl}^*}.
$$

(18)

Technique inventors also proposed to use information about prevailing perceptions of problem impacts and problem character to associate the experts who shared them. For example, the analysis of matrix $\mathbf{M}_3$ components resulted in the conclusion that the six most common direct problem impacts were perceived as the most important by 11 out of 32 experts. Note that similar analysis could be also conducted to associate experts who shared opinions about the most popular relationships and character of problems related to a specific issue e.g. living conditions in underdeveloped countries.

Another original proposal dealt with the possibility to analyse the degree of compliance of expert
opinions about actual direction of direct problem impacts. This was why a quadratic \( n \) by \( n \) binary matrix \( G^{(k)} \) was applied in the case of the \( k \)-th consecutive expert. An element \( g_{ij}^{(k)} \) of the matrix was utilised to express the direction of direct impact of the \( i \)-th consecutive problem on the \( j \)-th consecutive problem, according the \( k \)-th consecutive expert. Thus, matrix elements \( g_{ij}^{(k)} = 1 \) denoted that, according to \( k \)-th the expert, the \( i \)-th consecutive problem influenced the \( j \)-th consecutive problem, whereas \( g_{ij}^{(k)} = 0 \) meant no influence of the \( i \)-th consecutive problem at all:

\[
\forall k=1..K \quad \forall i,j=1..n \quad g_{ij}^{(k)} = \begin{cases} 
1 & \text{for } x_{ij}^{(k)} > 0, \\
0 & \text{otherwise.}
\end{cases} \quad (19)
\]

DEMATEL inventors noticed that the maximal number of possible disagreements between two experts was equal to number of elements of matrix \( G^{(k)} \) i.e. \( n^2 \). They proposed, therefore, to express the level of compliance for the \( k \)-th consecutive expert and the \( 1 \)-consecutive expert by means of \( \Delta g_{ij} \) indicator:

\[
\forall k=1..K \quad \forall i,j=1..n \quad \Delta g_{ij} = n^2 - \sum_{k=1}^{n} \sum_{j=1}^{n} |g_{ij}^{(k)} - g_{ij}^{(1)}|.
\]

It was also proposed to use similar way to analyse the compliance of experts with regard to character of distinct problems. Information provided in distinct rows and columns of matrices \( G^{(k)} \) and \( G^{(1)} \) was applied in this regard. The maximal number of possible disagreements equaled to \( n \) for each considered problem. Thus, the following indices, analogous to (20), were finally introduced:

\[
\forall k=1..K \quad \forall i=1..n \quad \Delta h_{i}^{+} = n - \sum_{j=1}^{n} |g_{ij}^{(k)} - g_{ij}^{(1)}| ; \quad (21)
\]

\[
\forall k=1..K \quad \forall i=1..n \quad \Delta h_{i}^{-} = n - \sum_{j=1}^{n} |g_{ij}^{(k)} - g_{ij}^{(1)}| , \quad (22)
\]

to express experts’ compliance with regard to causal and consequent character of the \( i \)-th consecutive problem, respectively. Note that the application of indices (21, 22) allowed Fontela and Gabus to draw interesting conclusions during original DEMATEL project implementation. This was because it turned out that engaged experts more often agreed to causality of problems than to their consequent character.

Note that in practice, we can’t expect perfect compliance of experts. This was also why DEMATEL inventors proposed to use a kind of a concordance threshold, which represented majority of possible 48 agreements. The application of the threshold which would actually allow to recognize sufficient compliance of experts’ opinions. It was finally set at 33 concordant opinions which corresponded with the majority of two thirds (2/3) of possible opinions plus one. The application of the threshold allowed Fontela and Gabus to divide 22 experts, who shared the same set of opinions about character of sufficient majority of problems, into 6 groups. Two major groups consisted of 6 and 8 members, respectively. Each of the remaining groups consisted of 2 members only. It was also impossible to group the remaining experts as they didn’t show a sufficient level of agreement with members of previously defined groups.

Results of the identification of groups of experts who share the same opinions about character of problems allowed DEMATEL inventors to indicate the most numerous groups. Such groups represented a consistent view of world’s problem. Therefore it was proposed to name such groups a “school of thoughts”. It was ultimately decided that only two large groups deserved to carry such name. Interestingly enough, the identification of two schools of thought found additional justification in radical differences in both represented views on world’s problems and a background of school of thought members. That was because one school of thought recognized a hierarchical structure of world’s problems and consisted of the representatives of administration and developed part of the world in general while the other favored network structure of inter-related world’s problems and gathered representatives of less-developed countries, religion, and science.

3.2. The analysis of indirect influence

Note that form of direct influence matrix \( X \) which satisfies the condition (3) implies that structure of indirect influence may be expressed by the following formula:

\[
\Delta X = X^2 (I - X)^{-1}.
\]

Information about indirect influence allowed Fontela and Gabus to propose to enrich their quest for the identification of actual structure of world’s problems by the analysis of the process of shaping a structure of total influence of problems.

3.3. Extra analysis of total influence

In addition to the obvious application of indicators (6, 7), when analyzing the structure of total influence, DEMATEL inventors also used measures (24–27), similar to (8–10), to determine the total impact of individual problems and total impact of
other problems on individual problems. The measures looked as follows:
\[ \forall_{j=1\ldots n} \sum_{i=1}^{n} t_{ij} ; \]  
\[ \forall_{j=1\ldots n} \sum_{i=1}^{n} f_{ji} ; \]  
(24)  
(25)  

in the case of general total influence analysis, and
\[ \forall_{j=1\ldots n} \sum_{i=1}^{n} f_{ij}^{(k)} ; \]  
\[ \forall_{j=1\ldots n} \sum_{i=1}^{n} t_{ij}^{(k)} ; \]  
\[ \forall_{j=1\ldots n} \sum_{i=1}^{n} f_{ji}^{(k)} ; \]  
(26)  
(27)  

in the case of analysis targeted at opinions of individual experts, where matrices of total influence \( T^{(k)} \) for individual experts resulted from the application of the following formula:
\[ T^{(k)} = X^{(k)} (1 - X^{(k)})^{-1} , \]  
(28)

whose validity depended on the satisfaction of the following condition:
\[ X^{*(k)} \rightarrow X^{(k)} : \lim_{m \to \infty} X^{(k)^m} = 0_{n \times n} . \]  
(29)

The indices (24–27) could be utilised for the identification of key problems according to total influence in similar manner like the indices (8–11) could be applied in the case of direct influence.

Another original DEMATEL suggestion was related to the analysis of total influence structure \( T \) (5) towards the identification of possible total influence feedback among problems. The application of special quadratic \( n \) by \( n \) binary matrix \( B \), analogous to matrix \( E \) (13), was proposed in this regard:
\[ \forall_{i,j=1\ldots n} b_{ij} = \begin{cases} 1 & \text{for } t_{ij} > 0, \\ 0 & \text{otherwise}, \end{cases} \]  
(30)

whose elements signaled the case of total influence of the \( i \)-th consecutive problem on the \( j \)-th consecutive problem (\( b_{ij} = 1 \)) and a lack of such influence (\( b_{ij} = 0 \)). The matrix was applied to define a quadratic \( n \) by \( n \) matrix \( C \), analogous to matrix \( F \) (14):
\[ C = B + B^T . \]  
(31)

Matrix \( C \) elements might correspond with a lack of any total influence (\( c_{ij} = 0 \)), total influence of one problem on the other one (\( c_{ij} = 1 \)) or total influence feedback (\( c_{ij} = 2 \)), in the case of the pair of the \( i \)-th consecutive problem and the \( j \)-th consecutive problem.

The ultimate proposal based on total influence structure use dealt with the comparison of divisions of problems into causes and effects obtained by different experts. Individual structures of total influence \( T^{(k)} \) (28) were utilised in this regard. The difference between corresponding row-wise sum and column-wise sum of matrix \( T^{(k)} \) elements:
\[ \forall_{k,l=1\ldots K} \forall_{j=1\ldots n} \sum_{i=1}^{n} \left( t_{ij}^{(k)} - \frac{1}{n} t_{ji}^{(k)} \right) \]  
(32)

was used to identify overall causal (\( \Delta t^{(k)}_{ij} > 0 \)) or consequent (\( \Delta t^{(k)}_{ij} < 0 \)) role of the i-th consecutive problem according to the k-th consecutive expert. The experts could be then associated with each other on the basis of sufficient number of concordant opinions about overall character of problems likewise the case of direct influence structure application (see: section 3.1).

4. Conclusions

DEMATEL technique is perceived as an established and very popular tool now (Sheng-Li et al., 2018). However, original reports of the inventors of the technique, which contemporary users of the technique are unaware of, show that only a part of original DEMATEL potential is exploited nowadays. This is why original features of the technique, which aren’t commonly known, are disclosed in the paper to make them available for the general public, again.

The results of the original application of the technique (Fontela & Gabus, 1973) are utilized in the paper to unveil the potential behind the disclosed technique features. It turns out that the application of the features may be particularly useful for the analysis of a character of collective and individual expert opinions and their effects as well as the analysis of a process of the development of total influence structure. The application of the features components not only may help in systematising the analyses and in the informed use of experts’ opinions but also facilitates acquiring of extra knowledge about actual features of a considered system. It can be finally concluded, therefore, that the application of disclosed original DEMATEL features may contribute to significant enrichment of the use and extension of application range of the technique.

Finally, it is worth emphasizing the original and source character of the work. This is because of the lack of access for general public to official reports which describe full version of the method and the motivation behind its invention. It may be treated, therefore, as a rare source material that can
contribute to the spread of full informed exploitation of DEMATEL technique potential amongst its contemporary users.

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GOOD NEWS FOR DEMATEL USERS: THE ORIGINAL POTENTIAL OF THE METHOD IS STILL AWAITING FULL EXPLOITATION


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