Influence Networks based Methodology for Consensus Reaching in Group-Decision-Making Problems

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Abstract. The purpose of this work is to show a way to improve agreement in group decision problems. This work focuses his effort on the issue refers to assign different importance to every decision-maker. We propose as a novelty a methodology to assign different levels of importance to every decision-maker according to their perceived importance in the group. First, judgments are collected by an html form and use a proposed method based on SNA and DEMATEL to assign weights to decision-makers according to their reputation in the decision-group. Next, we solve the problem using AHP in order to rank the alternatives.

Keywords: Influence · SNA · Consensus · Group-Decision-Making · MCDA · DEMATEL.

1 Introduction

Group decision-making problems present several issues to reach a consensus between decision-makers. According to [3,4] there are challenges and open questions according to represent a different level of importance to decision-makers. We propose that importance can be represented as weight over every decision-maker in order to influence a change over decision-makers initial judgments to reach a consensus agreement level over the main decision-making problem. There are many methods for weighting criteria, [1,17,29,28,25] Modeling a decision maker's preferences as tangible valuations of their value judgments or even quantitative information represents the core of the multi-criteria decision analysis. Determining correct valuations for the criteria and alternatives becomes a problem of vital importance in decision making. Determining this importance has been approached from multiple perspectives, among some of the best-known approaches, we can highlight the method of entropy, SWARA, SAW, AHP and ANP, among others. Even dematel presents a proposal to generate weights from the sets of importance and influence.

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2 Literature review and basic background

Groups have the potential to produce decisions that are better than individual ones. However, research and history show that groups can make worse decisions than individuals. even in the presence of diversity, strong leadership and unlimited time. The influence analysis has been developed from the social sciences, being psychology one of the branches that has presented more interest due to an extended use in the dynamics of group decision problems. Its historical evolution is shown below, emphasizing in the end the trend in applications related to multi-criteria analysis. According to [11] in 1950, many psychologists followed a research program on communication and social influence that focused on the foundations of power and influence in groups. Later, in 1970, interest in the field of group dynamics start to increase. While the increasing use of formal models tilts the field towards a concern with theoretical issues, the field is still far from having an adequate balance between theory, method and data. In the 1990s, [19] the most active lines of research in small groups were no longer in social psychology but in organizational psychology. However, even in organizational psychology, there has been a decline in work in human relationships and traditions of group dynamics exemplified by [16]. During the 1990s, more work was done in intergroup relationships, based on social cognition approaches, than in intergroup relationships, in which the structural characteristics of groups are recognized and treated. At the same time, intergroup relationship research moves to other fields of application. The social influence network theory presents a formalization of the social process of attitude changes that develop in a network of interpersonal influence [10,9,11]. [21] suggests, that the emergence of interpersonal influence is among the basic postulates of social psychological theory: *People's attitudes are usually formed in interpersonal settings in which influential positions on issues disagree and may change.* The social influence network (SIN) has been continuously developed since the 1950s by [14,13,6,10]. It is one of the important fields directly related to group decision making and SNA. In this co-related direction, recent studies on CGDM have been introduced with the incorporation of the theory of social influence, derived from social networks. Brunelli et al. He addressed the evaluation of consensus considering the strengths of the influence of experts in a social network through a measure of centrality of their own vector with a blurred adjacency relationship approach. In [15], a leadership-based consensus procedure was developed, where opinion managers can give advice and influence the formation of a social network's judgment to achieve consensus.

3 Methodology

For solve large group decision problems we propose a hybrid methodology based on [24,12,23,22] using Social network analysis/DEMATEL for assign weights to DM and analytic hierarchy process (AHP) for solve the decision-making problem. As novelty we include a weighting rule (eq. 15)

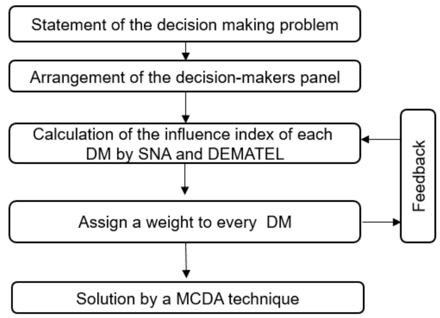


Fig. 1: Step by step methodology

The methodology can be seen in the fig. 1. First, we generate the visualization an analysis of data obtained by all decision-makers (DM). We collect all data by a html questionnaire shared with several D-M, in order to obtain the value-judgments of them. For data visualization and analysis of all decision makers we use JULIA programming language with the packages `Taro, DataFrames and ExcelReaders`. Second, we assign weights to all decision-makers as the arithmetic mean of SNA and proposed DEMATEL. Finally, we assign weights to all decision-makers and solve the problem with an MCDA technique, in this case, we propose to use AHP by an own developed package in Julia [4]. The use of SNA, DEMATEL and AHP is explained as follows.

3.1 Social Network Analysis

According to [2] social network analysis is a collection of techniques under a methodology that allows us to create social structures by using graph theory and network analysis. Social structures can represent several kinds of different relationships between actors and assign weight to those relationships. It can represent the spread of disease or virus, interpersonal relationships, trust, influence, among many others. According to [18] SNA practice, it implies following an analysis structure that suggests the following steps (adapted for our context in decision making by the authors):

- **Identification:** In this paragraph we notice the advice from [2] and define relational states as ”relational cognition” in perceptual aspects. (Influence among them)
- **Analysis:** Measure the level of proximity for every decision-maker in the influence network, to assign them different levels of importance.
- **interpretation of information:** Assign weights for every decision-maker to use their influence in a dynamic group decision-making problem and improve consensus in their judgments.

[4] https://github.com/jorgeiv500/AnalyticHierarchyProcess

There are many proximity measures, in this work we use the measure [27]. The proximity can be compute as follows:

$$C_c^{'}(n_i) = \frac{g-1}{\sum_{j=1}^{g} d(n_i, n_j)} \tag{1}$$

Where: $d(n_i, n_j)$ is the distance between the actor n_i and the actor n_j, g is the sum of actors present in the network. The proximity measure proposed by Sabidussi can be seen as the average inverse distance between the actor (interested party in our problem) and all other actors. Proximity is the inverse measure of centrality because large values indicate that a node has high peripheral value, and small values indicate greater centrality in a node. A higher proximity index indicates less importance for each actor.

Decision-makers weight calculation The importance index is represented as the weight W_j of each DM when an opposite measure I is normalized as follows:

$$I = \frac{1}{C_c^{\prime}(n_i)} \tag{2}$$

Being I the importance of each DM n_i represented as the influence over all the DM and W_i is the weight for each DM.

$$W_i = \frac{I_i}{\sum_j I_i} \tag{3}$$

3.2 Decision-Making Trial and Evaluation Laboratory (DEMATEL)

Decision Making Trial and Evaluation Laboratory, was developed by [7,8] based on structural modeling for solving complicated and intertwined problems. According to [20], this method has his core on graph theory which can divide multiple criteria into a cause-and-effect group and the causal relationships in a network. This technique has extended use, so it can calculate the relations between criteria for Analytic-network-problems and other MCDM methods. In this method each node represents an evaluation item (like criteria, people, alternatives, among others), and arcs represent the strength of their relations. First, using a four values scale where every influencing factor is denoted by:

- No influence $\longrightarrow$ 0
- Low influence $\longrightarrow$ 1
- Medium influence $\longrightarrow$ 2
- High influence $\longrightarrow$ 3
- Very high influence $\longrightarrow$ 4

We invite experts denoted as H_i to obtain the direct influence matrices B_H. Every decision-maker give their judgments over the evaluation items with the scale presented before.

$$B_H = \begin{pmatrix} 0 & b_{12} & b_{1n} \\ b_{21} & 0 & b_{2n} \\ x_{n1}^k & x_{n2}^k & 0 \end{pmatrix} \tag{4}$$

Where $b_{i,j}$ represents the direct influenced matrix determined by the $H-th$ expert.

Next, we compute the average matrix as the arithmetic mean of all B_H matrices.

$$A = [b_{ij}]_{n\times n} = \begin{bmatrix} 0 & \frac{1}{H}\sum_{h=1}^{H} b_{12}^h & \frac{1}{H}\sum_{h=1}^{H} b_{1n}^h \\ \frac{1}{H}\sum_{h=1}^{H} b_{21}^h & 0 & \frac{1}{H}\sum_{h=1}^{H} b_{2n}^h \\ \frac{1}{H}\sum_{h=1}^{H} b_{n1}^h & \frac{1}{H}\sum_{h=1}^{H} b_{n2}^h & 0 \end{bmatrix} \tag{5}$$

Where A is the average matrix. Then, using eq 6 we normalize the average matrix A. The normalized initial direct-relation matrix R can be obtained as follows:

$$R = \frac{1}{v}A \tag{6}$$

Where the normalizing factor v is given by

$$v = \max_{i,j=1,..,n} \left\{ \sum_{j=1}^{n} b_{ij}, \sum_{i=1}^{n} b_{ij}, \right\} \tag{7}$$

Later, we compute the total relation matrix T. The powers of R represent the indirect effects between any factors. A continuous decrease of the indirect effects of factors along with the powers of matrix R, such as $R^2, R^3, R^4, ..., R^n$ like a Markov chain matrix, guarantees convergent solutions to the matrix inversion. Then, the total relation matrix X is given as follows:

$$T = R + R^2 + R^3 + \ldots = R(I - R)^{-1} \tag{8}$$

Where I is $n \times n$ unit matrix.

The total effect that directly and indirectly exerted by the ith factor, is denoted by r_i , could be calculated as follows:

$$r_i = \sum_{j=1}^{n} t_{ij} \tag{9}$$

The total effect including direct and indirect effects received by the jht factor, id denoted by c_j could be calculated as follows:

$$c_j = \sum_{i=1}^{n} t_{ij} \tag{10}$$

Decision-makers weigths calculation According with [1,5] DEMATEL can be used in order to compute the weights of criteria in MCDM problems as follows.

$$r_i + c_i = t_i^+ = \sum_{j=1}^{n} t_{i,j} + \sum_{j=1}^{n} t_{j,i} \tag{11}$$

where t_i^+ represents the importance factor of every evaluated item.

$$r_i - c_i = t_i^- = \sum_{j=1}^{n} t_{i,j} - \sum_{j=1}^{n} t_{j,i} \tag{12}$$

where t_i^- represents the influence factor of every evaluated item.

$$w_i = ((t^+)^2 + (t^-)^2)^{1/2} \tag{13}$$

where w_i represents euclidean distance of every evaluated factor, and consider the importance $t_i^+$and influence t_i^- of all nodes.

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{14}$$

Finally, we normalize matrix w_i and obtain the weights for all item under evaluation.

Proposed method for weighting based on DEMATEL influence t_i^- Given that we want to see the influence of every DM into all other participants, we propose: from eq 12 obtain influence values of every decision-maker, similar to centrality values we obtain the capacity of change judgments over other decision-makers. Later, we show their similarities with a numeric example in the last section of this paper. We propose only use the influence t_i^-, as positive values by adding the double of the absolute value from a minimum of all negative values in set t_i^-.

$$W(t_i) = \begin{cases} \frac{w_i}{\sum_{i=1}^{n} w_i} & \text{if any } t_i^- \exists \{\mathbf{R}<0\} \\ \frac{t_i^-}{\sum_{i=1}^{n} t_i^-} & \text{if } t_i^- \in \{\mathbf{R} \geq 0\} \end{cases} \tag{15}$$

where $W(t_i)$ is the final weigth for every decision-maker, t_i^- is the influence vector and $\omega_i = t_i^- + 2|\min_{i=1}^{n} t_i^-|$ are positive values from t_i^-.

3.3 Analytic hierarchy process

For solving the DM problem, we propose the use of AHP, as an accepted and used often in problems that include subjective judgments of people. According to Saaty [26,25] the AHP is a useful tool to structure complex problems that influence multiple criteria and at the same time classify a set of alternatives in order of importance. Initially a hierarchical structure is made where the main decision problem is identified, then the criteria and sub-criteria that are taken into account for the decision are identified.The last level corresponds to the set of alternatives that will be evaluated concerning each of the criteria and sub-criteria. This evaluation is carried out through a series of binary comparisons in a matrix n x n, where n is the number of elements to be compared. In order to make the comparison, a scale is required. He proposed a scale between 1 and 9 where each intermediate value has an interpretation for the decision-maker (see Table.1).

Table 1: Saaty scale

Relative Intensity	**Definition**
1	Equal importance
3	Moderate importance of one element over another
5	Strong importance of one element over another
7	Very strong importance of one element over another
9	Extreme importance of one element over another

Values 2, 4, 6 and 8 are intermediate values that can be used in some cases. The next step is to find the relative priorities of the criteria and / or the alternatives. This step is based on the eigenvector theory. For example if a comparison matrix is A, then:

$$Aw = \lambda_{\max} w \tag{16}$$

Where w corresponds to the column vector of the relative weights obtained by making the average of each line of the normalized comparison matrix.

The value of $\lambda_{\max}$ is obtained by adding the column vector corresponding to the multiplication of the original comparison matrix with the column vector of relative weights.

$$\lambda \max = \sum_{i}^{n} Aw \tag{17}$$

Because comparisons are made subjectively, a consistency index is required to measure the consistency of the person making the ratings. The consistency index and the consistency ratio CR are calculated as follows:

$$CI = \frac{\lambda_{\max} - n}{n-1} \qquad CR = \frac{CI}{RI} \tag{18}$$

Where the RI inconsistency ratio is a comparison constant that depends on the size of the paired comparison matrix for sizes of n = 9 (our criteria x criteria matrix) RI = 1.45

4 Solution method

- **Decision-Making Problem Formulation:** We use a HTML survey [5] form in order to collect judgments for 6 Decision Makers.
- **Data Management and implementation SNA-DEMATEL:** The implementation of SNA was made with Gephi and calculating in Julia Language the Sabidussi proximity measure.
- **Decision-Making Problem solution:** For solve the DM problem, we first compare and assign a weight to every DM in order to give them different levels of importance. Next, we solve the problem using AHP and arithmetic mean aggregation of their judgments.
- **IDE:** IPython/IJulia/Jupyter-notebooks.

4.1 Case Study in environmental decisions

Decision-Making Problem Formulation: The primary purpose of this application is to compare DEMATEL with SNA to assign weights to decision-makers. To solve the DM-Importance issue, we analize the problem presented in [24]. This problem includes new six decision-makers as stakeholders in a group decision-making problem. The main problem is to prioritize environmental issues in a natural park. The criteria describe as follows.

Criteria The set of criteria is given in order to prioritize the problems given as conservation objectives for the Cocuy National Natural Park.

- Keep the eco-systemic connectivity of forest areas and wilderness.
- Preserve habitats and populations of endemic species.
- Keep the water supply that feeds the river basins.
- Protect the Uwa territory that overlaps with the Park.
- Protect outstanding scenic values.

Alternatives After discussing with the panel of decision-makers, it was agreed to use 6 problems present in the National natural park.

- Socio-Political fragmentation and loss of traditional knowledge of Uwa community.
- Logging, burning and clearing of vegetation to maintain pastures and crops between the Andean forests in the eastern sector.
- Infrastructure without environmental impact studies and mitigation measures (deposits, canals, bridges, roads)
- Extensive grazing in the park.
- Clogging and rapid drying of peatlands, lakes and springs
- Tourism poorly managed in the park.

[5] https://www.1ka.si/

Data Management and implementation SNA-DEMATEL: In order to implement SNA and DEMATEL we make a square matrix for every DM collecting the perceived importance of each other DM. Next, according with [24] we calculate the influence index for every DM, by asking the decision makers the following question: *"Q1. Which stakeholder do you think may agree with your opinion regarding the ranking of the goals of Cocuy National Park?"*. Each DM gives his/her opinion (their own beliefs) in order to build the square matrix following the scale:

- No agreement with your opinion = 0
- Low level of agreement with your opinion = 1
- Medium level of agreement with your opinion = 2
- High level of agreement with your opinion = 3
- Very high level of agreement with your opinion = 4

The judgments for every decision maker (also called matrix A See eq.5) can be observed in Table 2 their aggregation and normalization (also called matrix D See eq.6) can be observed in Table 3.

$$A = \begin{pmatrix} 0.00 & 2.33 & 2.33 & 2.33 & 2.50 & 3.67 \\ 1.83 & 0.00 & 2.50 & 3.00 & 2.67 & 2.17 \\ 1.00 & 2.00 & 0.00 & 1.50 & 1.83 & 1.00 \\ 1.67 & 3.17 & 1.83 & 0.00 & 1.67 & 1.83 \\ 1.67 & 1.67 & 1.83 & 2.17 & 0.00 & 3.00 \\ 1.50 & 1.50 & 1.83 & 1.83 & 1.83 & 0.00 \end{pmatrix} D = \begin{pmatrix} 0.00 & 0.18 & 0.18 & 0.18 & 0.19 & 0.28 \\ 0.14 & 0.00 & 0.19 & 0.23 & 0.20 & 0.16 \\ 0.08 & 0.15 & 0.00 & 0.11 & 0.14 & 0.08 \\ 0.13 & 0.24 & 0.14 & 0.00 & 0.13 & 0.14 \\ 0.13 & 0.13 & 0.14 & 0.16 & 0.00 & 0.23 \\ 0.11 & 0.11 & 0.14 & 0.14 & 0.14 & 0.00 \end{pmatrix}$$

Table 3: Aggregation A and Normalization D, also called D matrix

	DM1	**DM2**	**DM3**	**DM4**	**DM5**	**DM6**
DM1	0	0.2	0.2	0.2	0.214	0.314
DM2	0.16	0	0.214	0.257	0.229	0.186
DM3	0.09	0.171	0	0.129	0.157	0.086
DM4	0.14	0.271	0.157	0	0.143	0.157
DM5	0.14	0.143	0.157	0.186	0	0.257
DM6	0.13	0.129	0.157	0.157	0.157	0

From Table 3 we apply DEMATEL and Social Network Analysis in sub section Decision-making problem solution as follows.

Table 2: Influence values for every decision maker DM

(a) Decision maker 1

	DM1	DM2	DM3	DM4	DM5	DM6
DM1	0	3	3	3	3	4
DM2	2	0	3	3	2	2
DM3	1	1	0	2	1	1
DM4	1	3	3	0	1	3
DM5	2	1	2	3	0	3
DM6	1	2	2	1	2	0

(b) Decision maker 2

	DM1	DM2	DM3	DM4	DM5	DM6
DM1	0	2	3	3	2	4
DM2	2	0	3	3	3	3
DM3	1	2	0	2	2	0
DM4	2	4	1	0	2	2
DM5	1	2	2	1	0	3
DM6	2	1	2	3	2	0

(c) Decision maker 3

	DM1	DM2	DM3	DM4	DM5	DM6
DM1	0	3	2	2	3	4
DM2	2	0	2	3	3	0
DM3	1	3	0	1	2	1
DM4	2	3	2	0	2	1
DM5	1	2	2	2	0	4
DM6	1	2	1	1	2	0

(d) Decision maker 4

	DM1	DM2	DM3	DM4	DM5	DM6
DM1	0	2	2	3	3	3
DM2	1	0	3	3	3	3
DM3	1	2	0	0	2	2
DM4	1	3	2	0	2	2
DM5	2	2	1	2	0	3
DM6	2	1	2	2	2	0

(e) Decision maker 5

	DM1	DM2	DM3	DM4	DM5	DM6
DM1	0	2	2	0	2	3
DM2	2	0	2	3	2	2
DM3	1	2	0	2	2	1
DM4	2	3	1	0	3	2
DM5	2	1	2	2	0	3
DM6	2	1	2	2	2	0

(f) Decision maker 7

	DM1	DM2	DM3	DM4	DM5	DM6
DM1	0	2	2	3	2	4
DM2	2	0	2	3	3	3
DM3	1	2	0	2	2	1
DM4	2	3	2	0	0	1
DM5	2	2	2	3	0	2
DM6	1	2	2	2	1	0

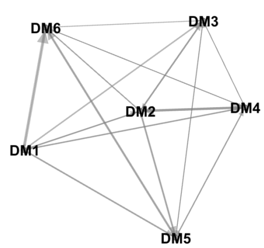


Fig. 2: Influence Network in Gephi®

$$C_i = \begin{pmatrix} 0.38 \\ 0.75 \\ 1.50 \\ 1.43 \\ 1.36 \\ 2.00 \end{pmatrix} \quad I_i = \begin{pmatrix} 2.63 \\ 1.33 \\ 0.67 \\ 0.70 \\ 0.73 \\ 0.50 \end{pmatrix} \quad W_i = \begin{pmatrix} 0.40 \\ 0.20 \\ 0.10 \\ 0.11 \\ 0.11 \\ 0.08 \end{pmatrix} \tag{19}$$

Decision-Making Problem solution: For **SNA** analysis we take the D matrix and represent the strength of all influence-relations in a graph (with gephi software) as we can see in Fig 2. Their importance is calculated by Sabidussi centrality/proximity measure [27]. Once we have the Sabidussi centrality C_i we apply the eq.2 and 3 in order to calculate the weight (importance) for every decision maker (see eq. 19). Next, we aplly **DEMATEL** also starting from matrix D, next using eq 6 we obtain the direct relations matrix, then we also get the total relation matrix T from eq 8 (see Table 4)

$$T = \begin{pmatrix} 0.44\ 0.73\ 0.72\ 0.74\ 0.73\ 0.85 \\ 0.53\ 0.55\ 0.69\ 0.74\ 0.71\ 0.72 \\ 0.34\ 0.49\ 0.35\ 0.46\ 0.47\ 0.45 \\ 0.47\ 0.68\ 0.59\ 0.49\ 0.58\ 0.63 \\ 0.47\ 0.58\ 0.58\ 0.62\ 0.46\ 0.69 \\ 0.40\ 0.50\ 0.51\ 0.53\ 0.51\ 0.42 \end{pmatrix} \tag{20}$$

In order to identify the relevant relations between decision-makers we give a

Table 4: total relation matrix T, r and c values

	DM1	**DM2**	**DM3**	**DM4**	**DM5**	**DM6**	***r***
DM1	0.439451	0.731664	0.717209	0.741951	0.733089	0.846074	**4.209**
DM2	0.533578	0.549456	0.690697	0.742677	0.70559	0.720201	**3.942**
DM3	0.339858	0.48739	0.345787	0.464839	0.472036	0.449336	**2.559**
DM4	0.473047	0.676942	0.588607	0.488866	0.584842	0.6284	**3.441**
DM5	0.466728	0.582645	0.57874	0.617774	0.461313	0.688785	**3.396**
DM6	0.402952	0.503124	0.510324	0.527189	0.514534	0.424408	**2.883**
c	**2.656**	**3.531**	**3.431**	**3.583**	**3.471**	**3.757**	

threshold value $\beta = 0.6$ (0.1 over the arithmetic mean of every b_{ij} given in the matrix T). In Table 4 we can see all important relations between decision-makers (in green) and represent them in DEMATEL (see Fig. 3) relations graph. The final ranking for DEMATEL importance and influence can be observer in Table 5b as follows:

Finally, we solve the problem using AHP though superdecisions-software [6]. Table 5a shows the weight compatibility between the proposed SNA and DEMATEL approach. Weights obtained using the proposed DEMATEL approach have been compared with those obtained with Social network analysis by heighteningsabidussi proximity measure (see Fig. 4 as follows).

Comparing them, there are very similar and present compatibility in their order of preference, obtaining the same selection results when apply AHP method as can see in Figs 5 and 6.

[6] https://www.superdecisions.com

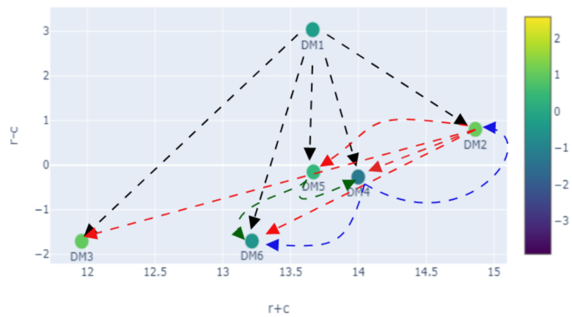


Fig. 3: DEMATEL importance $r + c = t_i^+$ and influence $r - c = t_i^-$ with their Relationships from X matrix

Table 5: Influence values for every decision maker DM

(a) DM final weights

	Sabudussi SNA W_i	**Proposed Dematel** W_i
DM1	0.40	0.31
DM2	0.20	0.21
DM3	0.10	0.08
DM4	0.11	0.15
DM5	0.11	0.16
DM6	0.08	0.08

(b) Influence $r - c$ and Importance $r + c$

	r	***c***	***r+c***	***r-c***
DM1	4.21	2.66	6.87	1.55
DM2	3.94	3.53	7.47	0.41
DM3	2.56	3.43	5.99	-0.87
DM4	3.44	3.58	7.02	-0.14
DM5	3.40	3.47	6.87	-0.08
DM6	2.88	3.76	6.64	-0.87

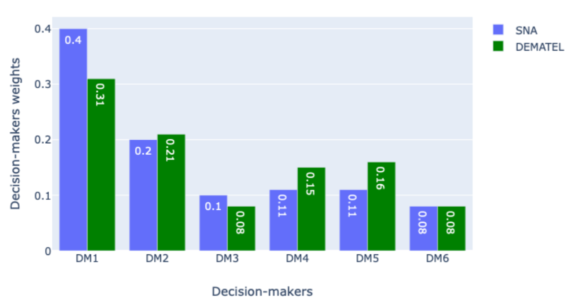


Fig. 4: Decision-makers final weigths

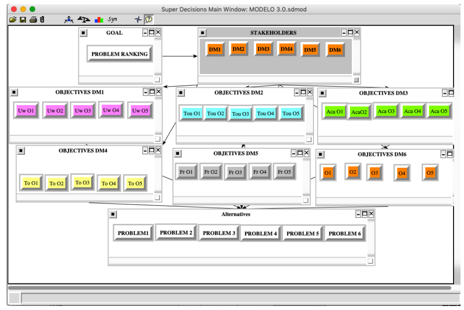
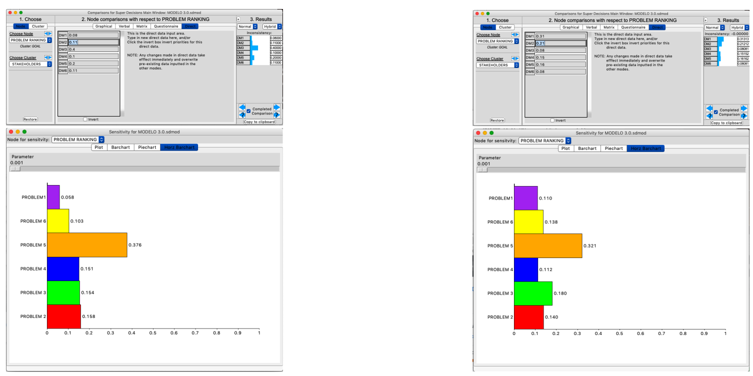


Fig. 5: AHP Decision-model using Superdecisions software



(a) AHP model results using SNA (b) AHP model results using DEMATEL

Fig. 6: AHP model results with proposed models using Superdecisions

Now, we replace weights with arithmetic mean of two proposed approaches and obtain as result: $Aw_i = \{0.360.200.090.130.140.08\}$ and alternatives solution

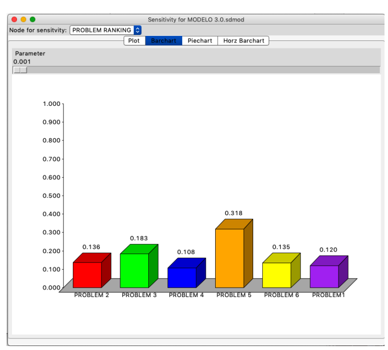


Fig. 7: Final Ranking with Superdecisions

ranking for the problem: $S_i = \{0.140.180.110.320.140.12\}$. As can see in Fig. 7 Problem 5 is the most important problem in this numerical example, and there is an agreement of every decision-makers over the solution, reaching consensus over the final rank.

5 Conclusions

- Sabidussi proximity measure give ssimilar results to Normalized DEMATEL proposed weighting method, both proposals are normalized and proportional.
- It is possible to influence change over judgments in a decision-makers group by an iterative and dynamic way, showing the values of the actor that have major influence over all.
- People tend to agree with judgments from the most influential actor, given their importance perception over some participants in the decision-making group.
- Group decision making presents several issues according to every different context in decision-making formulation. However, one of the open challenges can be solved by our proposal in a very effective way, giving to every decision-maker a perceived-influence by other members of the decision group.
- In addition, to compute weights for every decision-maker, social network analysis and DEMATEL give the analyst in the group decision problem the capacity of increasing their knowledge about hidden relationships over participants and give an easy way to reach agreements faster than other panel-based-methods.

References

1. BaykasoğLu, A., KaplanoğLu, V., DurmuşOğLu, Z.D., ŞAhin, C.: Integrating fuzzy dematel and fuzzy hierarchical topsis methods for truck selection. Expert Systems with Applications **40**(3), 899–907 (2013)
2. Borgatti, S.P., Everett, M.G., Johnson, J.C.: Analyzing social networks. Sage (2018)
3. Cabrerizo, F.J., Pérez, I.J., Herrera-Viedma, E.: Managing the consensus in group decision making in an unbalanced fuzzy linguistic context with incomplete information. Knowledge-Based Systems **23**(2), 169–181 (2010)
4. Cabrerizo, F.J., Chiclana, F., Urena, M., Herrera-Viedma, E.: Challenges and open questions in soft consensus models. In: 2013 Joint IFSA World Congress and NAFIPS Annual Meeting (IFSA/NAFIPS). pp. 944–949. IEEE (2013)
5. Dalalah, D., Hayajneh, M., Batieha, F.: A fuzzy multi-criteria decision making model for supplier selection. Expert systems with applications **38**(7), 8384–8391 (2011)
6. DeGroot, M.H.: Reaching a consensus. Journal of the American Statistical Association **69**(345), 118–121 (1974)
7. Fontela, E., Gabus, A.: Dematel, innovative methods (1974)
8. Fontela, E., Gabus, A.: The dematel observer (1976)
9. Friedkin, N.E.: A structural theory of social influence, vol. 13. Cambridge University Press (2006)

10. Friedkin, N.E., Johnsen, E.C.: Social influence and opinions. Journal of Mathematical Sociology **15**(3-4), 193–206 (1990)
11. Friedkin, N.E., Johnsen, E.C.: Social influence network theory: A sociological examination of small group dynamics, vol. 33. Cambridge University Press (2011)
12. Gelvez, J., Aldana, F.C., Sepúlveda, G.: Mining method selection methodology by multiple criteria decision analysis—case study in colombian coal mining. In: International Symposium of the Analytic Hierarchy Process, Washington DC, USA (2014)
13. Harary, F.: A criterion for unanimity in french's theory of social power. (1959)
14. Johnsen, E.: Studies in multiobjective decision models. Studentlitteratur Lund (1968)
15. Kamis, N.H., Chiclana, F., Levesley, J.: An influence-driven feedback system for preference similarity network clustering based consensus group decision making model. Information Fusion **52**, 257–267 (2019)
16. Katz, L.: A new status index derived from sociometric analysis. Psychometrika **18**(1), 39–43 (1953)
17. Keršuliene, V., Zavadskas, E.K., Turskis, Z.: 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 (2010)
18. Khan, G.F.: Seven Layers of Social Media Analytics: Mining Business Insights from Social Media Text, Actions, Networks, Hyperlinks, Apps, Search Engines, and Location Data. Gohar Feroz Khan (2015)
19. Levine, J.M., Moreland, R.L.: Progress in small group research. Annual review of psychology **41**(1), 585–634 (1990)
20. Lin, C.J., Wu, W.W.: A causal analytical method for group decision-making under fuzzy environment. Expert Systems with Applications **34**(1), 205–213 (2008)
21. Newcomb, T.M.: Social psychological theory: integrating individual and social approaches. (1951)
22. Romero Gelvez, J.I.: Selección de métodos extractivos y su impacto en la productividad minera. estudio de caso en la minería de carbón colombiana (Diciembre 2012)
23. Romero-Gelvez, J.I., Cortes-Aldana, F.A., Franco-Sepulveda, G.: Compromise solutions in mining method selection - case study in colombian coal mining. DYNA **82**, 127 – 136 (06 2015)
24. Romero-Gelvez, J.I., Garcia-Melon, M.: Influence analysis in consensus search—a multi criteria group decision making approach in environmental management. International Journal of Information Technology & Decision Making **15**(04), 791–813 (2016)
25. Saaty, T.L.: What is the analytic hierarchy process? In: Mathematical models for decision support, pp. 109–121. Springer (1988)
26. Saaty, T.L., Peniwati, K.: Group decision making: drawing out and reconciling differences. RWS publications (2013)
27. Sabidussi, G.: The centrality index of a graph. Psychometrika **31**(4), 581–603 (1966)
28. Shannon, C.E., Weaver, W.: The mathematical theory of communication (urbana, il (1949)
29. Simos, J.: Evaluer l'impact sur l'environnement: Une approche originale par l'analyse multicritère et la négociation. In: Evaluer l'impact sur l'environnement: une approche originale par l'analyse multicritère et la négociation. Presses polytechniques et universitaires romandes (1990)