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Assigning Decision Makers' Weights Using TOPSIS Method In Spatial Multicriteria Group Decision Support System

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Abstract— Weights of decision makers (DMs) play an important role in multiple attribute group decisionmaking problems, and how to attribute these weights is an exciting research topic.The latter problems constitute real organizational architectures where the decision is characterized by several criteria and involves different decision-makers (DMs) with different perspectives. In this paper, a weighting module is integrated into a webbased intelligent multi-criteria group decision support system. The latter module is responsible for weights assignement to DMs. It is based on a multi-criteria method called "Technique of Order Preference Similarity to the Ideal Solution" (TOPSIS). The main idea is to obtain a ranking of decision-makers (from best to worst) according to various alternatives, and then use the Softmax function to determine their weights based on the TOPSIS ranking values. The new module was tested on a real case study in territorial planning. The obtained results demonstrate the impact of the weighting procedure on the final decision in the decisional process, as the final decision was influenced by the weight values assigned to DMs (importance degree). Future work will improve the weighting module to handle additional types of data, such as linguistic or fuzzy numbers.

Index Terms—Group Decision Support System, Multiple Criteria Analysis, TOPSIS, Weighting methods**.**

I. INTRODUCTION

The term "group decision support system" (GDSS) refers to a system that helps people make decisions in groups. It is a computer-based system that often consists of a number of different interfaces and panels. The basic purpose of GDSS is to help a group of individuals (organizations) working on a decision-making challenge achieve a common goal (compromise decision) despite their divergent interests and preferences.[29]

Multiple attribute decision making (MADM) is an important component of decision science, it is composed of multiple attribute (criteria) and a set of decision alternatives. The purpose of decision making is to choose the best option(s) from a finite number of viable possibilities based on a set of caracteristics. The classification of decision in Figure 1 aids in the building of GDSS models. The decision is separated into two portions in the latter figure, depending on the number of participants and the degree of authority held by each of them (in case multi-participants). The decision is divided into two parts:

- Individual where only one decision maker is involved in the process.
- Multi-participant in which a group of people makes a decision; this section is split into two branches:
  - Unilateral decision making: which refers to a situation in which a single decision maker makes a decision with the help of others.
  - Negotiated decision making: this category is defined as a decision in which authority is distributed among a number of decision-makers; it is divided into two sub-branches:
    - Group: refers to a situation in which all participants have equal authority over the final decision.
    - Organization: means that each one of the participants has a different authority.

The degree of importance ascribed to the decision maker in the decision-making process, or in simplest terms; "the weight" determines his or her authority. The purpose of weighting is to express the influence (contribution) of each decision maker

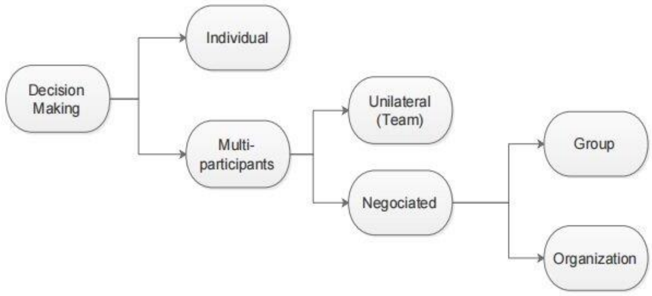

Figure 1: Decision classification. source([3])

on the final choice; therefore, assigning a weight to each of them is highly significant and necessary.

The goal of this research is to apply a weighing technique based on the work in [33] for decision makers in WIM-GDSS platform established in [20]. The authors of the latter work assumed that all decision makers on the platform have the same authority over the final decision; their work falls under the Group category (Figure 1), whereas in real-world organizations, decision makers often have different influences on the decision process, necessitating the development of a method to determine the appropriate weight values for each of them. The proposed approach uses a multi-criteria method called TOPSIS [12], [4]. It was inspired by the results presented in [33], in which the authors developed an approach for group decision-making based on dermining decision makers' weights us ing the TOPSIS method. The current paper is organized as follows, in section II the related works are presented, in section III the motivation and main contributions of this work are depicted, section IV illustrate the methodologies used in this paper, containing a brief description of WIM-GDSS, and an illustration the weighting approach, In section V a real case study of decision-making in territory planning is presented using the same example as in WIM-GDSS [20], finally in section VI the paper is concluded with a conclusion, limitations and perspectives.

II. Related work

A vast range of strategies are available in the literature, each with its own set of benefits and drawbacks. The selection of these approaches and their placement in each level of the GDSS is a critical issue that must be handled with care due to the significant impact on system performance and user convenience.

Many GDSS in the literature, including the system in question in this study [20], consider the decision makers within to be of similar importance (Group category in Figure 1) [10], [24], [18], and in the majority of them, no weight is applied, which is the same as allocating equal values. There are two different ways to implement the weight, objectively by using statistical methods or subjectively by determining it in accordance with certain preferences and considerations [31], [2], as some academics feel that weight is a subjective judgment [32], [8].

Analytical techniques are very important and effective for generating critical decisions when using it in weighting models within GDSS (multi-criteria decision-making (MCDM) [15], hybrid MCDM [17], fuzzy hybrid [14], Delphi [19], weighted power–weakness ratio (wPWR), simple additive ranking (SAR) and Kendall–Wei method (KW) [28] and other weighting techniques).

Several methods uses MCDM models such as simple additive weighting (SAW) in [5], weighted product (WP) in [12], TOPSIS [33], analytic hierarchy process (AHP) in [25], [21] and Borda in [7] or with the approach of fuzzy multicriteria decision-making (FMCDM) [1]. In general, weighting models with MCDM [15] or hybrid MCDM [9], [16], [30] are used to solve GDSS problems. The weighting method with MCDM has been developed or combined by incorporating fuzzy set theory, as developed in [5], [11], [27], [34], [6]. MCDM determines the interest weight of each criterion to be applied to the GDSS model based on the effect on the interests of benefit and cost, as in SAW, Borda, and others. Another GDSS weighting model is the social network (SN) model, which was developed [23] to link the relationship between DMs [35]. Other notions in weighing are needed depending on the expert opinion or social relationships of each DM's influence in decision making.

III. Motivations and contribution

The motivation for this work is to adapte WIM-GDSS to real-world organizational decision making problems; for the latter problems, decision makers involved has different authority over the final decision, the goal is to obtain the best solution among other feasible ones, or in different terms (technicly speaking) the closest option to the ideal solution. Since it is a group decision-making problem all participants must be implicated therefore each one of them should have an importance degree, for that purpose it is crucial to attribute weights adding more importance to the decision makers who have the best suggestion, and less importance to the others.

The main contributions of this study are:

- Imporving WIM-GDSS by adding a weighting module responsible for attributing decision maker's weights (Figure 2).
- Applying a weighting approach based on TOPSIS method and softmax function for weight

assignement in a real case study in territory planning.

- The weighting approach is flexible; it assigns weights to decision makers based on their contribution to the decisional problem at hand (different weights for each problem).
- The weighting approach is not subjective; there is no need to evaluate decision makers (saaty scale) a priori.

IV. METHODOLOGIES

A. DESCRIPTION OF WIM-GDSS

WIM-GDSS stands for Web Intelligent Multi criteria Group Decision Support System, and as the name suggests, the system is built on a web architecture to help decision makers communicate and collaborate from afar (users). As shown in Figure 2, WIM-GDSS combines four tools: a multiagent system to model decision makers and their human behavior, a multi-criteria analysis to deal with multi-attribute decision-making problems, a geographic information system to account for the spatial aspect of the decision-making problem, and artificial intelligence to mimic human intelligence by adding a prediction ability to virtual agents within. WIM-GDSS is enhanced with a coordination protocol that allows decision makers involved in the process to communicate preferences in order to arrive at a compromise solution that satisfies the majority of them, ensuring easy collaboration between the agents. The agents could predict the ranking of alternatives' outcomes using a linear regression model trained on TOPSIS results, that is, the model predicts TOPSIS results after adding the matrix of performances and criteria weights (subjective parameters). It should be noted that the decision makers do not introduce crisp values as criteria weights, but rather linguistic values for a pairwise comparison between the criteria, which will be aggregated as a matrix and utilized as an input for the AHP method [26] to obtain the weight values for the criteria. Each decision maker in the decision-making process will be given a ranked vector of alternatives (objective vector) based on his or her preferences. The objective vector is ranked according to the value assigned to each option; the higher the value, the better the option. The initiator agent will aggregate all of the decision makers' objective vectors to build the group matrix of performance (GMP). The GMP is a model of a collective decision-making problem. The weighting of decision makers must be implemented at this stage of the process (the aggregation module [20]); the goal of this research is to add a weighting module after this stage of the WIM-GDSS process. The new module is in charge of assigning the proper weights to each of the participants.

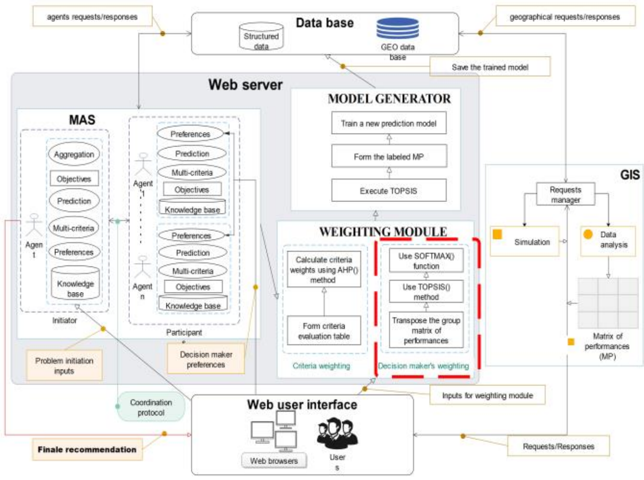

Figure 2 : Globale architecture of WIM-GDSS.

B. The Weighting Approach

The group matrix of performances (GMP) is a two-dimensional matrix in which the rows represent the various alternatives and the columns represent the decision makers, while the values represent the decision maker's evaluation of each alternative, with higher values indicating better performance. As demonstrated in Figure 3, the purpose of the weighting module is to obtain a ranking of decision makers from best to worst based on their contribution to the decision process regarding several alternatives. The main idea is to use the TOPSIS method, but first the GMP matrix must be transposed to put decision makers in rows and alternatives in columns so that the multi-criteria method can order them from best to worst. TOPSIS produces an ordered two-dimensional vector of decision makers, each of which is associated with a real value representing its evaluation. The softmax function (Equation 1) is then applied to the resulting vector as the final step. The goal of using it is to obtain the probabilities that sum to one of the given vectors, which is a crucial feature of weighting (Equation 2).

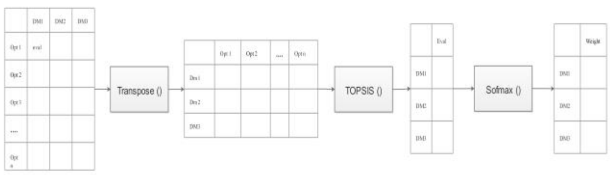

Figure 3: The weighting approach procedure.

$$Soft\max(z)_i = \frac{\exp(z_i)}{\sum_j^k \exp(z_j)}, i=1,\ldots,k \quad z=(z_1,\ldots,z_k) \qquad (1)$$

$$\sum_{j=1}^{n} w_j = 1, j = 1,\ldots,n \qquad (2)$$

C. Why TOPSIS

Topsis stands for "Technique of order preference similarity to the ideal solution" and is a simple multi-criteria decision analysis method (MCDA). It was presented by [12], [4] and is one of the classic MCDA methods that has attracted a lot of interest from researchers and scientists. The objective behind this strategy is to find an ideal and an anti-ideal solution and then compare the distance between each of the options and those. The authors chose this method due to the following reasons [22]:

- It has been applied and approved by re searchers in a variety of application areas.
- It has been successfully applied to group decision problems.
- Its simplicity and Straightforwardness, (simple to understand and to code)
- It doesn’t have a lot of parameters that could influence the final result.
- The final score of each alternative could be calculated separately and independently from other alternatives.
- Its capacity to deal with a large number of alternatives

D. Why SOFTMAX function

The values of the TOPSIS resultant vector do not sum to 1, and hence cannot be utilized as weights (equation 2 is not verified). as a result, the softmax function was chosen by the authors in this study. The second reason is that some values within the input vector may be negative, which might be an issue for many normalization methods (although it is impossible with topsis but could appear with another MCMA method).

V. CASE STUDY

The authors give an instructive example of a decision-making dilemma in this part; to that aim, the case study in WIM-GDSS [20] will be used.

A. The Addressed Problem

The case used in this current study was brought up by Joerin [13] and treated also by [10]. The study area is located in the canton de Vaud in Switzerland, about 15 kilometers from Lausanne, and has an area of about 52 000 km2. Its geographical limits in the Swiss coordinating system are 532 750-532 500 (m) and 158 000-164 000 (m) (m). In addition to 650 empty lots (alternatives), seven criteria were defined based on a variety of factors (environmental, social, economic, etc.): harm, noise, impacts, geotechnical, and natural risks, equipment, accessibility, and climate. Figure 4 depicts the performance matrix for the problem under consideration; The aim is to rank a collection of empty zones to assist decision-makers in choosing the best appropriate zone for the construction of a dwelling. Three decision makers are involved in the decisional process.

N°	ID_ZONE	HARM	NOISE	IMPACTS	GEOTECH	EQUIP	ACCESS	CLIMATE
1	202	1,00	0,68	0	1	816	8	0,92
2	209	1,00	0,45	0	1	1249	9	0,91
3	210	1,00	0,69	0	1	1165	9	0,89
4	211	1,00	0,48	0	1	1518	9	0,92
5	213	1,00	0,92	0	1	1356	9	0,89
6	215	1,00	1,00	0	1	1434	8	0,75
7	216	1,00	0,97	0	1	1490	10	0,83
8	218	1,00	1,00	0	1	1556	8	0,70
9	219	1,00	1,00	0	1	1638	12	0,68
10	220	1,00	1,00	0	1	1629	8	0,68
11	221	1,00	0,95	0	1	1641	10	0,84
12	223	1,00	1,00	0	1	1697	8	0,68
13	224	1,00	0,98	0	1	1758	10	0,70
14	225	1,00	1,00	0	1	1801	8	0,67
15	226	1,00	0,91	0	1	1809	10	0,84
16	228	1,00	1,00	0	1	1840	8	0,67
17	229	1,00	0,97	0	1	1870	10	0,68
18	230	1,00	0,09	0	1	1848	12	0,55
:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:
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644	9516	1,00	1,00	6	6	1568	6	0,69
645	9517	1,00	1,00	6	6	1569	8	0,67
646	9519	0,57	0,82	6	6	1589	10	0,47
647	9525	1,00	0,98	6	6	1766	12	0,07
648	9534	1,00	0,26	6	6	1912	11	0,39
649	9548	1,00	0,14	6	6	2240	12	0,66
650	9550	0,00	0,03	6	6	2012	10	0,54

Figure 4: The matrix of performances

B. The Decision-making Process

Table I shows the criteria weights introduced by each decision maker, it represent their preferences over the criteria.

Table 1: Criteria weights

	Harm	**Noise**	**Impacts**	**Geotech**	**Equipement**	**Access**	**Climat**
DM_1	0.142	0.142	0.142	0.142	0.142	0.142	0.142
DM_2	0.383	0.242	0.153	0.096	0.061	0.038	0.024
DM_3	0.111	0.154	0.093	0.059	0.029	0.531	0.020

The TOPSIS method is applied to the weighted matrix of performances by each decision maker, resulting in a vector of alternatives with a ranking value. The vectors of all decision makers are then combined to generate a group matrix of performances. Figures 5 and 6 show the group matrix of performances (GMP) and its transposed matrix (GMPT), respectively.

ID_ZONE	SCORE1	SCORE2	SCORE5
202	0,258965104139	0,281899368112	0,157621404689
209	0,258970134833	0,281897883703	0,157645995363
210	0,258971662308	0,281901455964	0,157647436613
211	0,258971612713	0,281898872962	0,157646343640
213	0,258974456515	0,281905423301	0,157648991617
215	0,258968515417	0,281905195121	0,157623580996
216	0,258980144930	0,281907681068	0,157675123666
218	0,258968451051	0,281905319447	0,157623594910
219	0,258990078860	0,281910813274	0,157726843568
...	...	...	...
9519	0,258993469606	0,281916757986	0,157680318266
9525	0,259005066414	0,281930663926	0,157734278010
9534	0,258997600132	0,281918929069	0,157704365554
9548	0,259006324867	0,281919547989	0,157729889312
9550	0,258984820119	0,281893132135	0,157673456689

Figure 5: Group matrix of performances

	202	209	210	211	213	215	216	...
DM1	0,258965104139	0,258970134833	0,258971662308	0,258971612713	0,258974456515	0,258968515417	0,258980144930	...
DM2	0,281899368112	0,281897883703	0,281901455964	0,281898872962	0,281905423301	0,281905195121	0,281907681068	...
DM5	0,157621404689	0,157645995363	0,157647436613	0,157646343640	0,157648991617	0,157623580996	0,157675123666	...

Figure 6 The transposed matrix of performances

Table II illustrate the resulting vector of TOPSIS method, every decision maker is associated with a ranking value illustrating the corresponding importance regarding the treated problem. As noticed from Table II; the ranking values does not sum to one (which is a crucial caractaristic of weights), hence the authors employed the softmax function

that aims to return a values that sums to one in accordance with the given vector.

Table 2: TOPSIS evaluations

Decision-maker	Evaluation
DM_1	0.37074148
DM_2	0.40356465
DM_3	0.22569387

Table III depicts the final vector of decision makers' weights; the values within sums to one (Equation 2).
Table III clearly shows that the weights assigned to decision makers correspond to the TOPSIS method values; that is, the decision maker with the highest contribution value (DM2) is assigned the highest weight value, and vice versa.
After assigning weights to decision makers, the weighted group matrix of performance is calculated using those values. The final solution will be computed using the latter matrix. Figures 7 and 8 shows the group solutions obtained with and without weighting respectively, the group solutions obtained differ; the final ordered vector of alternatives differs after using the weighting approach, which is due to the impact of the attributed weights.

Table 3: Decision-makers' weights

Decision-maker	Weights
DM_1	0.34502402
DM_2	0.35653671
DM_3	0.29843926

RANK	ID_ZONE	SCORE
1	3701	0,000512960622
2	8930	0,000512960355
3	649	0,000512959257
4	8747	0,000512957198
5	549	0,000512956314
6	1045	0,000512955855
7	3401	0,000512952695
8	3822	0,000512949889
9	3817	0,000512949056
10	943	0,000512948301
...	...	...

Figure 7: group solution with equal DMs weights

RANK	ID_ZONE	SCORE
1	1045	0,000514390227
2	3701	0,000514389148
3	8930	0,000514388692
4	649	0,000514387649
5	8747	0,000514385478
6	549	0,000514384579
7	3822	0,000514384137
8	3817	0,000514383330
9	943	0,000514382394
10	3820	0,000514381536
...	...	...

Figure 8: Group solution with different DMs weights

CONCLUSION

Multiple attribute group decision-making (MAGDM) problem constitute an important part of decision science, many practical situations are modeled by MAGDM, in this kind of problems, decision makers (DMs) often have different degree of authority over the final decision, therefore attributing weights is a key matter. There are many techniques to attribute these weights, depending on the problem at hand, one of the most simple and straightforward method is to use a multi-criteria method to rank and order DMs in accordance to a ranking value. In this paper the authors used a weighting approach based on Zhongliang's work in [33], they used TOPSIS method to get a ranking of decision makers and softmax function to turn the ranking values into weights that sums to one. The weighting approach was used as the main core of a weighting module added to a platform called WIM-GDSS (web intelligent multi-criteria group decision support system) [20]. The latter module allows the platform to attribute weights to decision makers within based on their contribution to the decision-making problem treated. The proposed approach does not support attribute values other than crisp number, it should be improved to take into account other forms of data such as linguistic or fuzzy numbers.

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