Another way of looking at group decision making opens new perspectives.

Wim De Keyser
SIA, Hemelstraat 90, 9200 Dendermonde, Belgium

Johan Springael
Vakgroep MTT, UA, Middelheimlaan 1, 2020 Antwerpen, Belgium

Abstract: Group Decision Support Systems usually use a multiple criteria method as an engine to obtain the group's ranking of the alternatives. Intermediate results of this multiple criteria method are aggregated over the different group members to come to a final result. Another approach consists of considering the different rankings of the alternatives -one ranking for each group member- and to find the ranking that best fits these different rankings. Hereto, a measurement must be defined that indicates how well a ranking fits a given set of rankings. The problem then reduces a combinatorial optimisation problem since for a given number of alternatives, the number of possible rankings, including the possibilities of ties, is defined in a combinatorial way. In this paper such a measurement is defined. It also explores the new perspectives this approach offers to group decision making.

Keywords: GDSS, Group Decision Making, Multicriteria analysis

1. Introduction

Nowadays, during a GDSS-procedure the group of involved decision-makers must agree upon almost all aspects of the decision problem: the alternatives, the criteria and the evaluations of the alternatives on each criterion. On top of that, they must agree on the multicriteria method that will function as the engine to obtain the group's ranking of the alternatives. Depending on the used multicriteria method, they must comply with the way it captures their individual and personal view at the problem, and with the values of certain "common parameters" of this multicriteria method. Each of these points can be a source of discussion amongst the decision-makers and – for the decision-maker(s) that must bow for the point of view of the group – a source of disagreement with the used approach and/or the final group decision.

Several main general approaches can be distinguished to handle a GDSS-process, where p decision-makers are involved and where the problem at hand is well outlined. These existing structures or procedures are briefly explained in section 2.

In the authors' opinion the GDSS-procedure must provide as much freedom as possible to the decision-makers with respect to their decision-process. In order to allow this freedom, we conceived a new approach to GDSS, which is presented in section 4.

For this new GDSS approach, a measure is needed, indicating how well a ranking fits a given set of rankings. This is done in section 5.

In section 6 it is shown that, for a given number of alternatives, the number of possible rankings, including the possibilities of ties, is defined in a combinatorial way and that e.g. simulated annealing can be used to obtain the "best" (most appropriate) ranking. The impact of this new approach on several aspects of GDSS are discussed in section 6, while in section 7 some results of this approach are presented. Some conclusions are made in section 8.

2. The different GDSS approaches.

In this section we will briefly describe the main properties of GDSS's based on multicriteria methods. A common property of most existing GDSS's is that the decision problem, including the alternatives, the different criteria and the evaluations of the alternatives on the criteria, is determined by the group. Hence, it is presupposed that the group has already reached a consensus with respect to the aforementioned inputs of the decision problem. Even the multicriteria method, which will be used by the group, is supposed to be known to every decision-maker of the group, who implicitly agrees with its use.

a. First type of GDSS's.

In the first approach of GDSS's the so-called "decision-maker"-specific data, such as preferences, importances of criteria, ..., required for the selected multicriteria method, are determined by the group. In order to obtain the group decision, the multicriteria problem is then solved by means of the chosen method, after which it is presented to the decision-makers for final acceptance or discussion. In figure 1 the general structure of this type of GDSS's is presented.

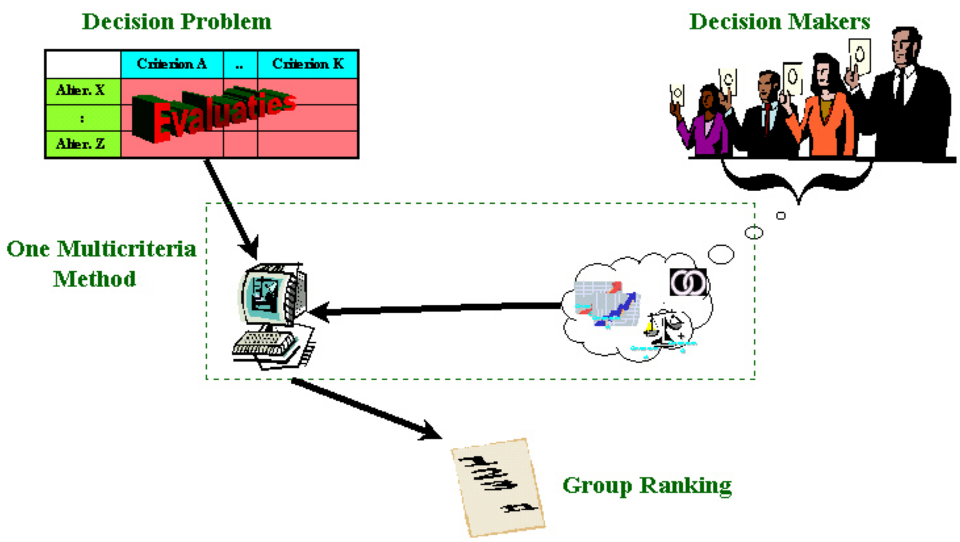


Figure 1 : First type of GDSS's

b. Second type of GDSS's.

The second type of GDSS's supposes that the decision problem (alternatives, criteria, evaluations) is determined by the group in the same manner as for the first type. Though the "decision-maker"-specific data such as preferences, importance's of criteria, … required for the selected multicriteria method are determined separately for each decision-maker. Hence, *p* multicriteria problems with the same problem data (alternatives, criteria, evaluations), but with different "decision-maker"-specific data are considered.
To obtain the group decision, the *p* multicriteria problems are each solved using the chosen multicriteria method until a certain point. At that point, intermediate results of the *p* multicriteria problems are aggregated and from there on the multicriteria method continues as if it is solving a single multicriteria problem.
Afterwards the result is considered as the group decision, which is then presented to the decision-makers for final acceptance or discussion. In figure 2 a schematic representation of this second type of GDSS's is shown.

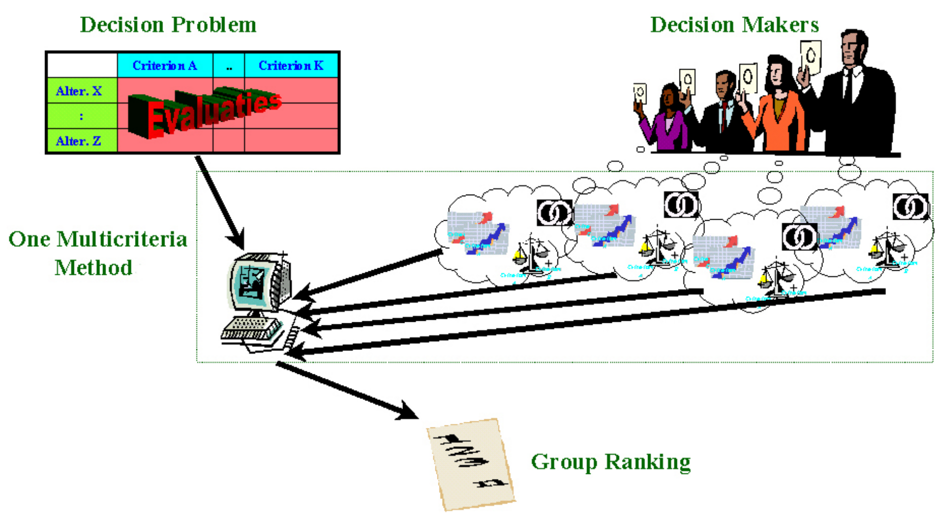


Figure 2 : Second type of GDSS approaches

c. Third type of GDSS's.

In the same way as for the former types the decision problem (alternatives, criteria, evaluations) is determined in group, and as for the second type, for each decision-maker the "decision-maker"-specific data such as preferences, importances of criteria, … required for the selected multicriteria method are determined.
Again *p* multicriteria problems with the same problem data (alternatives, criteria, evaluations), but with different "decision-maker"-specific data are considered, which are separately solved by means of the chosen multicriteria method. This results in *p* rankings, where each ranking has a preferential structure, i.e. an end result from the used multicriteria method.
In a second stage the *p* rankings with their preferential structures are considered as a decision problem. The "decision-maker"-specific data is obtained from a "Supra Decision-maker" and this multicriteria problem is solved (usually with the same multicriteria method as the one of the previous stage). The result of this is considered as the group decision, which is then presented to the decision-makers for final acceptance or discussion.
A scheme of this third type of GDSS's can be found in figure 3.

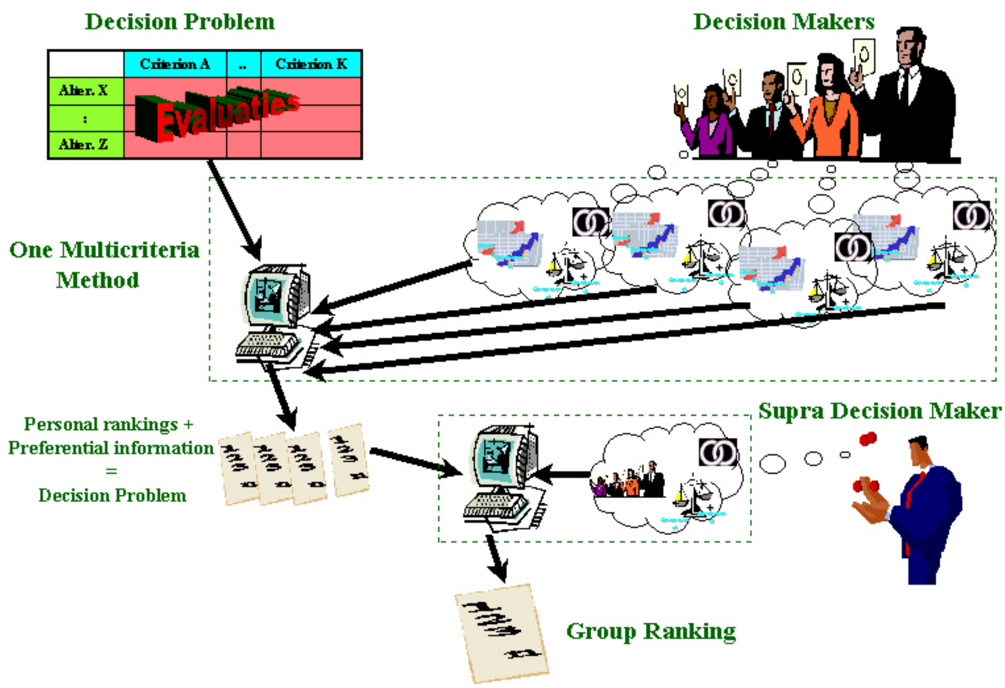


Figure 3 : The third GDSS approach.

3. A new type of GDSS approach.

Consider another approach to GDSS in which the decision-makers should only agree upon the alternatives and their location in the complete list, which should be completely independent ranking. The problem of ending with a group decision can then be formulated as: "Consider *p* different rankings of *n* alternatives – one ranking for each member of the group – find the ranking that fits best these different rankings."

This new GDSS approach, where *p* decision-makers are involved and where the problem at hand is well outlined, can be summarised as follows:

- A part of the decision problem (alternatives) is determined in group;
- A part of the decision problem (criteria, evaluations) can be determined in group or by each decision-maker individually;
- Each decision-maker chooses the multicriteria method he wants to use;
- For each decision-maker "decision-maker"-specific data such as preferences, importances of criteria, ... are determined according to the multicriteria method he has chosen;
- *p* multicriteria problems with not necessarily the same problem data (same alternatives, but criteria and/or evaluations can be different), with different "decision-maker"-specific data are considered;
- The *p* multicriteria problems are solved using the different multicriteria methods involved and results in *p* rankings of the alternatives;
- Determination of the consensus ranking that fits best these *p* different rankings;
- This group decision is then presented to the decision-makers for final acceptance or discussion.

Figure 4 gives a schematic view of this new type of GDSS approach. It clearly shows the important difference between the former types of GDSS's and the one proposed in this paper.

However, in order to make this new GDSS approach work, a measure must be defined that indicates how well a ranking fits a given set of rankings. This measure will be described in the following section.

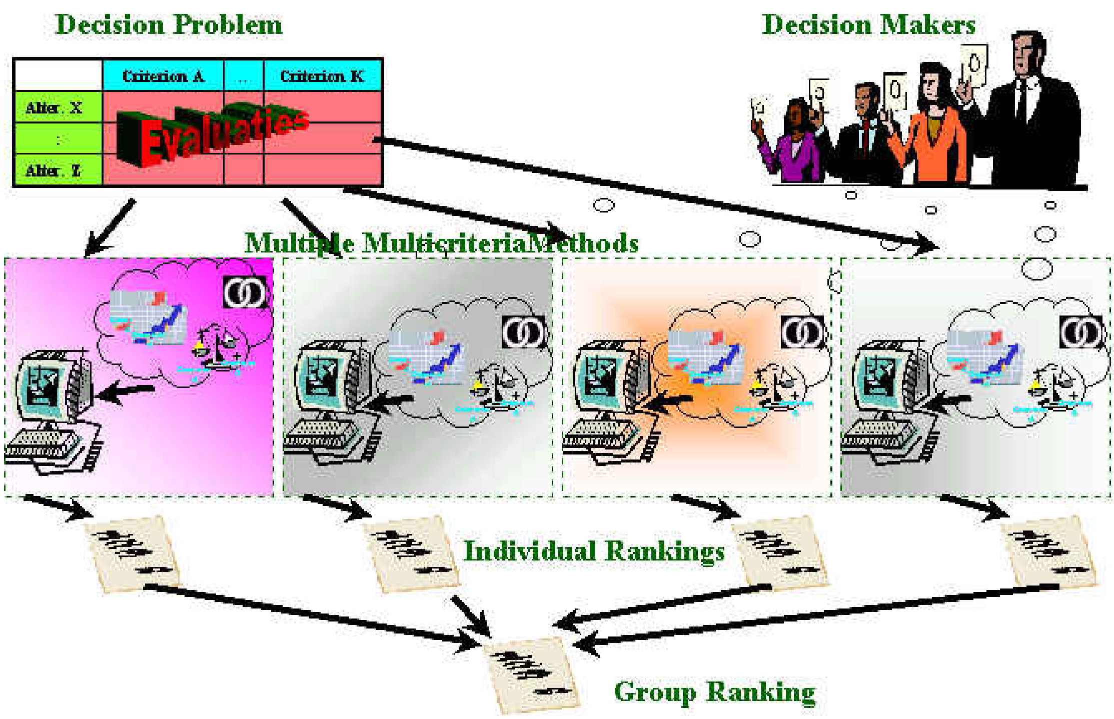


Figure 4 : A new GDSS approach

4. An appropriate measure for comparing rankings.

In this section a measure that indicates how well a ranking fits a given set of rankings is built. This is done in two steps.
First a measure of how well a ranking fits another ranking is selected. Since ranking is done on an ordinal scale, the rank correlation coefficient of Kendall (1938) is the obvious choice. Comparing a ranking with *p* other rankings results in *p* rank correlation coefficients.
Secondly, the median of the *p* rank correlation coefficients is taken.
Note that a ranking of the *n* alternatives can contain ties. In order to take these into account one should use an adapted version of Kendall's rank correlation coefficient (see e.g. Spitz (1971) for a clear description).

The measure, as describe above, can also be seen as a measure for the "conformity" of the group decision. The higher the value of the measure, the higher the probability that the individuals within the group will accept and validate the group's decision.
A way of measuring the "opposition" against the group decision is to take the lowest rank correlation coefficient between a decision-maker's ranking and the group ranking. The lower this value, the higher the probability that at least one decision-maker will make objections against the group's decision.

Looking for a ranking that maximizes the median of the *p* rank correlation coefficients, indicates that one wants at least half of the *p* decision-makers to have the same or higher rank correlation coefficient between their ranking and the group ranking. In other words, one is looking for a group decision by majority. Instead of the median, the 33-percentile can be used. With this kind of measure one wants a $^2/_3$-majority.
Finding the ranking that maximizes the lowest rank correlation coefficient of the *p* rank correlation coefficients can be used when looking for an unanimous decision.
Of course other percentiles can be used, but the aforementioned ones are in the context of group dynamics the most likely.

5. The combinatorial optimisation problem.

Consider *n* alternatives $(a_1, a_2,..,a_n)$. A ranking of the alternatives can be represented by an *n*-tuple indicating for each alternative its rank number, e.g. (3,1,...,4) is a ranking of $(a_1, a_2,..,a_n)$ where a_1 is at rank 3, a_2 is at rank 1,... and a_n is at rank 4.
How many different rankings can be made ? Since there can be ties, the number of ranking groups *g* is at least equal to 1 and at most equal to *n*. It is clear that each ranking group contains at least one alternative and each alternative must belong to a ranking group. Thus, for a given number of ranking groups *g*, the number of different rankings is given by a permutation – with repetition – of *n* elements with amongst them q_1 of rank 1, q_2 of rank 2, ... and q_g of rank *g* . This can be described as :

$$\sum_{\substack{\sum_{j=1}^{g} q_j = n \\ q_j \in \mathbb{N}_0 \; j=1,\dots,g}} \frac{n!}{q_1!.q_2!...q_g!}$$

Note that when *g = 1* there is only one possible ranking and when *g = n* there are *n!*

possible rankings.

It can be shown that there are $\frac{(n-1)!}{(g-1)!.(n-g)!}$ different possibilities for giving positive, non-zero integer values to q_j $j=1,..,g$ such that $\sum_{j=1}^{g} q_j = n$.

The total number of different rankings is :

$$\sum_{g=1}^{n} \sum_{\substack{\sum_{j=1}^{g} q_j = n \\ q_j \in \mathbb{N}_0 \; j=1,\ldots,g}} \frac{n!}{q_1!.q_2!\ldots q_g!}$$

Hence, the problem can be seen as a combinatorial optimisation problem and can be solved by using e.g. simulated annealing, which is the heuristic used in the software implementing these ideas.

Simulated annealing is a general heuristic method (it can be applied to a lot of combinatorial optimisation problems) for global optimisation and originates from an analogy between the physical annealing process and combinatorial optimisation. It is a rather "young" method (see S. Kirkpatrick et al, 1983) with "older" roots (see N. Metropolis et al, 1953) in the field of Statistical Mechanics.

6. The impact of freedom on several aspects of a GDSS

a. Impact on the choice of multicriteria method

In the Group Decision Support Systems approaches, described in section 2, a single multicriteria method is used as an engine. The selection of the multicriteria method that will be used as engine in the GDSS approach can give rise to discussion. One decision-maker may be convinced that e.g. the PROMETHEE-method (Brans and Vincke 1985) is the best method to model his "view" on the problem while another decision-maker only prefers the use of e.g. the ARGUS-method (De Keyser and Peeters 1994).

At a certain point in the calculations, when using the second GDSS approach, intermediate results are aggregated. It is clear that in order to aggregate these intermediate results –depending on the multicriteria method used – a common framework for the "decision-maker"-specific data is required. For example in the ARGUS-method, the number of balance levels must be the same for all decision-makers. This common framework can be experienced as a serious limitation that restricts the accurate modelling of every decision-maker's specific data.

Since the new GDSS approach only expects a ranking from each decision-maker, he is allowed to use whatever (multicriteria) method he likes and/or whatever framework for the "decision-maker"-specific data he prefers.

b. Impact on the choice of criteria

As part of the GDSS procedure, the criteria that will be used by the decision-makers are determined in group. The set of criteria that results from this group discussion is

not necessarily the same as the set of criteria that each individual decision-maker wants to take in consideration.
Besides the fact that not all suggested criteria are selected, which can be a potential source of disagreement for one or more decision-makers with the used approach and/or the (later on) obtained group decision, there is another aspect involved. During the group selection of the criteria, certain decision-makers can agree on the concept of a certain criterion, but disagree on the way this concept is filled in. For instance when a bank wants to decide to give a credit to an individual, they take a/o. “the stability of the client” into account. But this concept can be filled in in different manners: one bank translates this concept into two criteria/questions: “How many years are you working for your current employer?” and “How many years are you living at your current address?”. They could also ask : “For how many employers have you worked the last 10 years?” and “On how many addresses have you lived the last 10 years?”. Each set of criteria/questions will result in other answers, which can lead to different conclusions about the stability of the (potential) client.
It is clear that in the new GDSS approach each individual decision-maker can choose for himself which (concepts of) criteria he wants to take into consideration.
Note that the choice of criteria was already possible in the second and third GDSS approaches when a multicriteria method, where numerical weights are assigned by each decision-maker to the criteria (e.g. the PROMETHEE-method), is used as engine. By giving the weight 0, the decision-maker could exclude those criteria he (as an individual) does not want to take into account.

c. Impact on the choice of evaluations

It is not because decision-makers agree on a criterion that they automatically agree on the evaluations for each alternative on that criterion. For example in order to determine where to put another plant in Europe, the criterion “expected economical growth for next calendar year” is one of the selected criteria during a GDSS-process. What source will be used to fill in the evaluations for each European country? The European central bank, the government of each country, the opposition of each country, a (commercial) rating agency, in-house or out-house economical experts,…? Every decision-maker can have his own opinion about the reliability and/or the quality of the information supplied by a certain source.
In the first GDSS approach and in the second and third GDSS approaches, in the case where the multicriteria method that serves as an engine does not use numerical weights, only one source per criterion can be considered, while the proposed GDSS approach gives room for several sources. Each decision-maker can then select the source he “believes” in.

d. Impact on the availability of the decision-makers

The decision-makers are going (together) through the different steps of the GDSS-procedure. Normally the GDSS-process takes place at a fixed date and location. Hence the presence of all decision-makers is required during the whole GDSS-procedure in case it is of type 1.
The proposed GDSS approach requires only the presence of the decision-makers during the determination of the feasible alternatives and when the final group decision is presented for acceptance and/or discussion. For all other intermediate

steps, the decision-makers can operate separately and, if preferred, at other times and places.

e. Supra decision-maker

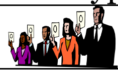
A supra decision-maker is required for the third type of GDSS approach, expressing the appreciation of the option of a particular decision-maker.
The other GDSS approaches are using more “democratic” rules to obtain the group decision. The proposed GDSS approach for example can support any “democratic” rule going from an anonymous decision over a two-third majority, over a simple majority to a minority decision.

7. Results

In order to test the feasibility of the approach described in this paper, a number of test cases were developed. Each of the test cases consists of a multicriteria problem and the “decision-maker”-specific data, needed for the ARGUS-method, for several decision-makers.
The multicriteria problems were solved with the ARGUS-method to obtain the individual rankings of the decision-makers. Then the combinatorial approach was used to obtain the group decision. Also an aggregation of the ARGUS-balances of the different decision-makers took place so that a solution obtain by an ARGUS-driven GDSS (second approach) was obtained.
The median Kendall rank correlation measure was uses as measurement of the “conformity” of the group decision. The lowest rank correlation coefficient of Kendall between a decision-maker’s ranking and the group ranking was taken as measurement of the “opposition” against the group decision. Both measurements were applied to both final results
The combinatorial approach resulted, for each test case, in a solution that is slightly better in “conformity” and slightly worse in “opposition” than the solution found with the ARGUS-driven GDSS.
During the tests, none of the above mentioned “relaxations” (see 6.) were applied. This was done to have a reference – the results with a second type of GDSS approach – in order to be able to compare with the results of the proposed GDSS approach. The tests have shown that the new GDSS approach gives feasible results and in further research, this GDSS approach will be used together with one or more “relaxations”.

8. Conclusions

In this paper we proposed a new structure for group decision support systems. In the proposed GDSS approach the decision-makers must only agree upon the alternatives while in the former GDSS approaches the decision-makers must agree and/or comply with several or all aspects of the decision problem and with several or all the methodological aspects of the used multicriteria method.

	GDSS approach type 1	GDSS approach type 2	GDSS approach type 3	GDSS approach New type
Alternatives				
Criteria		()	()	
Evaluations		()	()	
Multicriteria method				
"Common" MCDM parameters		()	()	
Supra Decision-maker				
Same time and place				

In the table above different aspects and properties of GDSS's are summarized. It is clear from this table that the proposed GDSS structure enables the decision-makers to make their own decision, with their own believes, numbers and methods, giving back their freedom with respect to the determination of their choice.
The first tests with this GDSS approach gave plausible results. This method has opened new perspectives and opportunities to Group Decision Making and will be applied on several real-life applications involving a group decision. The results of the latter will be the subject of another publication.

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