



**HAL**  
open science

## Choosing a Voting Procedure for the GDSS GRUS

Rachel Perez Palha, Pascale Zaraté, Adiel Teixeira de Almeida, Hannu Nurmi

► **To cite this version:**

Rachel Perez Palha, Pascale Zaraté, Adiel Teixeira de Almeida, Hannu Nurmi. Choosing a Voting Procedure for the GDSS GRUS. 17th International Conference on Group Decision and Negotiation (GDN 217), Aug 2017, Stuttgart, Germany. pp.163-174. hal-03624699

**HAL Id: hal-03624699**

**<https://hal.science/hal-03624699v1>**

Submitted on 30 Mar 2022

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



## Open Archive Toulouse Archive Ouverte

OATAO is an open access repository that collects the work of Toulouse researchers and makes it freely available over the web where possible

This is an author's version published in:  
<http://oatao.univ-toulouse.fr/19141>

**Official URL:** [https://link.springer.com/chapter/10.1007/978-3-319-63546-0\\_12](https://link.springer.com/chapter/10.1007/978-3-319-63546-0_12)

DOI : [https://doi.org/10.1007/978-3-319-63546-0\\_12](https://doi.org/10.1007/978-3-319-63546-0_12)

**To cite this version:** Perez Palha, Rachel and Zaraté, Pascale and Teixeira De Almeida, Adiel and Nurmi, Hannu *Choosing a Voting Procedure for the GDSS GRUS*. (2017) In: 17th International Conference on Group Decision and Negotiation (GDN 217), 14 August 2017 - 18 August 2017 (Stuttgart, Germany).

Any correspondence concerning this service should be sent to the repository administrator: [tech-oatao@listes-diff.inp-toulouse.fr](mailto:tech-oatao@listes-diff.inp-toulouse.fr)

# Choosing a Voting Procedure for the GDSS GRUS

Rachel Perez Palha<sup>1</sup>, Pascale Zarate<sup>2</sup>, Adiel Teixeira de Almeida<sup>1</sup>, and Hannu Nurmi<sup>3</sup>

<sup>1</sup>Universidade Federal de Pernambuco, CDSID - Center for Decision Systems and Information Development, Caixa Postal 7462, Recife, Pernambuco, 50630-970, Brazil

rachelpalha@cdsid.org.br

almeida@cdsid.org.br

<sup>2</sup>Toulouse University – IRIT, Toulouse, France

pascale.Zarate@ut-capitole.fr

<sup>3</sup>University of Turku, Turku, Finland

hnurmi@utu.fi

**Abstract.** In group decision-making, the use of Group Decision Support Systems is increasing and in some groups, a facilitator is required to improve communication among participants. The facilitator has several roles in this situation, which include helping decision makers (DMs) to decide which type of aggregation they would prefer in each decision context. Whenever DMs have different objectives regarding the same problem, they might decide a consensual decision is no longer possible. Therefore, other types of aggregation are required. Voting rules are strongly applied in this type of situation. However, the question that arises is: who should decide the voting method? In this article, a framework for choice of a voting procedure in a business decision context is used. It takes the facilitator's preferences into account while it seeks to choose which voting procedure best suits the environment of the Group Decision Support System GRoUp Support (GRUS).

**Keywords:** GDSS; facilitator; MCDM voting choice; choice of a voting procedure; preference analysis.

## 1 Introduction

Dufner *et al.* [1] state that most managers spend between 25% and 80% of their productive time in meetings trying to solve problems and make decisions focusing on shared objectives. They also verified that approximately 50% of this time is wasted due to information being lost and distorted, and because decisions made are suboptimal. They also state that it is a common belief that using Group Decision Support Systems (GDSS) may reduce these losses and increase the productivity of a group. Therefore, several GDSS have been proposed in the literature.

Colson [2] presented a modification to ARGOS, by adding a new feature: JUDGES. His objective was to provide a GDSS to help a jury choose the best student's final work by the Belgian Operations Research Society based on some criteria decided by the jury.

In the first part of the model, the jury uses ARGOS to individually evaluate each alternative by using ELECTRE [3] or PROMETHEE [4]. In the second part, JUDGES presents the jury with the aggregated results based on different methods: voting rules or consensus. Damart *et al.* [5] presented IRIS, which is based on ELECTRE-TRI and combines the disaggregation approach and preference elicitation. The profiles are defined *a priori*, and the weights and cutting level are defined by applying the disaggregation approach. The facilitator's role in this context is to help the DMs reach a consensus. FlowSort-GDSS [6] was proposed in the risk and reliability context but does not make use of a facilitator.

Problems in coordinating groups who use GDSS may arise, such as fragmentation into subgroups and overall confusion of group members as to who is responsible for what by when [1]. Colson [2] found that studies on GDSS are more concerned about facilitating group meetings than with the multicriteria framework itself. When a group has sub-divided into distributed groups, a challenge which the group needs to overcome is how best to tackle asynchronous mediated communication. Thus, Kim *et al.* [7] conduct a study to examine the effect of system restrictiveness under this type of environment.

What the role of the facilitator should be is a topic that has also been studied over the years [8]. Ackermann [8] interviewed group members in order to find out what their perception of the facilitator's role is and to address some practical suggestions from professionals working in this field. Other frameworks seek to help facilitators to focus on important issues regarding the use of GDSS and helping the group to interact and to build a model which reflects their shared objectives. See, for example, those proposed by Ebadi *et al.* [9] and Adla *et al.* [10]. Also, some electronic agents have been presented in different GDSS such as in Rigopoulos *et al.* [11] and Jahng and Zahedi [12].

There are GDSS where the group's intention is to reach a consensual decision, which prompts the facilitator to play a role where he/she has to help the group to discover their shared objectives, the available alternatives, and a compromise solution. In other contexts, the group does not wish to reach consensus, but some interaction is necessary. Therefore, group decision problems can be divided into two main streams: (1) the DMs share the same objectives concerning a problem and (2) the DMs have different objectives regarding a problem. In the latter, the DMs want to have their point of view considered in the analysis but are prepared to accept a decision different from their own in favor of the group's [13]. It is in this context that voting rules are frequently used to reach a single compromise solution.

Several voting rules have been presented over the years. They have different features and are applicable in different contexts. All authors who have presented such rules were trying to avoid different voting paradoxes [14]. These paradoxes may allow the analyst or one of the DMs, who plays the role of an analyst, to manipulate the system to their own personal advantage. Thus, de Almeida and Nurmi [15] proposed a framework to deal with the decision process related to choosing a voting procedure for a business organization. The idea of using such a framework is to reinforce the commitment of the DMs with the solution since all of them had the opportunity to get involved in the choice of the method. Some concern on how to choose multicriteria decision aiding (MCDA)

methods have been tackled in different contexts. Gillian *et al.* [16] emphasized that several MCDA methods are available and they are not compatible with every decision context. Therefore, the choice of the wrong method may drive the solution to be misleading or unsatisfactory, causing useful techniques to be judged inappropriate and losses in energy, time and money due to wrong decisions. The choice of the method can be analyzed as a multicriteria problem as well, and this choice depends on the type of problem, goals of the DMs and desired properties of the compromise solution [17]. De Almeida *et al.* [13] presented a twelve-steps procedure to guide the analyst in the choice of a method compatible with the problem faced, and the DM's rationality and objectives. In addition, Roy and Słowiński [18] formulated some questions to help the analyst in the choice of the MCDA method more compatible with the decision context faced.

Furthermore, it should be noticed the ethical issue behind this question. The analyst's preference on the method choice may have ethical considerations [13]. Rauschmayer *et al.* [19] brings such an ethical considerations regarding to the modeling process, particularly for the choice of the method and its parameterization. It must be taken into account that distortions in the results cannot be made for interests other than the DMs. Also, the assumptions of the model must be shared with the DMs.

In this article, the framework proposed by de Almeida and Nurmi [15] is used to choose a voting rule, compatible with a facilitator's preferences, that applies a GDSS to conduct a synchronous group decision process. The facilitator, in such a case, is not familiar with all voting rules. Thus, the choice of the more appropriate voting rule is not intuitive, and the use of the framework is justified. Since the DMs are not directly involved in this choice, it is more difficult for any one of them to introduce bias into the process and this framework might drive the whole process to a Social Choice compatible with the group of DMs.

The article is divided into four sections. In section 2 the context of the problem is presented, while section 3 presents the experimental application. Section 4 draws conclusions and indicates lines of future research that could be usefully developed.

## 2 Context of the Problem

A Group-Decision Support System (GDSS) built on a web-based platform, called GRoUp Support System (GRUS) [20], is modularized in order to allow a facilitator to build the best structure for the problem that is being analyzed. In this system, there are two types of users: decision makers (DMs) and a facilitator, who is responsible both for the protocol of the group decision process and for leading the interaction process. The DMs have to put forward their ideas as to the electronic interaction in the first step, called "brainstorming", where they suggest, be it anonymously or not, the criteria they believe to be related to the problem, and also alternatives for solving the problem.

Once the first step is over, the facilitator leads the group to a verbal interaction, where they have to cluster the criteria and alternatives. They finally evaluate the alternatives regarding these criteria. For these evaluations, a suitability equation function is required, which calculates the score of each alternative using Choquet Integral. This

function is a kind of preference criterion. Another calculation is made with the Simple Additive Weight (SAW) [21]. To reach a final decision, the facilitator has to lead a consensus process, which is usually time-consuming and wearing, in addition to which it is usual to face situations where the DMs have different objectives concerning the same problem.

Currently, the process implemented considers that the group members' objectives regarding the problem are the same. This is the first type of group decision problem presented by de Almeida *et al.* [13]. Therefore, the process was built to reach a consensual decision that has to be achieved in a face-to-face group meeting and will require DMs to change their positions until a potential commitment is found. The question that is addressed here is how to lead the process whenever the group members have different objectives for the problem.

When the DMs do not share the same objectives, even if they agree to evaluate the alternatives using the same criteria, they have different perceptions about the meaning of each criterion. In these cases, the DMs propose their individual ranking of the alternatives, and they are aggregated based on DMs' final choices. One way of running this type of aggregation is by applying a voting procedure. Several voting procedures have been proposed over the years. Nurmi [22] presented a comparative analysis and showed that each of the methods is associated with serious drawbacks.

Usually, an analyst is responsible for choosing a voting procedure that is compatible with the needs of the group to reach a group decision. The choice of the best voting rule has been discussed over the years in the literature [23] and how to define setting out to do this usually relies on the properties of each method. Thus, some articles have compared voting rules by considering some aspects related to the properties sought for in these methods [24–28]. The main problem is that it is usually the analyst who chooses the voting rule but he/she is not supposed to be the best person to make this choice since he/she will not deal with the consequences of the social choice, as discussed by de Almeida and Nurmi [15].

To allow the DMs to have their preferences considered in this analysis, de Almeida and Nurmi [15] propose a framework to aid the choice of a voting procedure for decisions in a business decision context. Nurmi [23] conducted a numerical application of this method by considering some of the voting properties, which are characterized by the capability of a rule to overcome a voting paradoxes, as criteria for analyzing the voting procedures, which played the role of alternatives. The main idea is to consider a decision matrix where the voting procedures are the alternatives that are evaluated by considering some criteria. These criteria are divided into two main streams: voting properties and criteria related to the context of the problem. The latter is associated with how easily they can be applied. The decision matrix is evaluated by using a multiple-criteria decision method, which is selected by considering the characteristics of the methods and the problem itself and guided by the procedure proposed by de Almeida *et al.* [13].

Since in the context of GRUS, the DMs do not undertake the decision process without a facilitator, and the group depends on the facilitator right from the very beginning of the process, it is important to apply the framework, thereby allowing the facilitator

to decide which voting procedure would be best suited for this application. The application of the framework avoids manipulation on behalf of one or more parties, even when it is applied considering the facilitator's preferences. The analysis of the ease of voting depending on the procedure was not considered, because the ranking of alternatives is delivered by the application itself, and does not require more cognitive effort from the DMs. Therefore, only the voting properties were considered in the analysis.

### 3 Experimental Application

In this study, one of the authors plays the role of the analyst or facilitator. She was interviewed to express her preferences regarding the selection of the voting procedure to be used to aggregate the group members' preferences in one experiment. A subset of methods was considered in this analysis. The voting rules considered were: Amendment [14], Copeland [22], Dodgson [22], Maxmin, Kemeny [29], Plurality [22], Borda [30], Approval Voting [31], Black [22], Plurality runoff [22], Nanson [32] and Hare [22]. Other methods might be available but were not considered in this analysis such as the quartiles method [33,34] and those that consider partial information [35,36].

In order to evaluate all alternatives, namely voting rules, voting properties were considered. The criteria used to evaluate the voting procedures were as follows:

(a) the procedure should always choose a Condorcet winner when there is one. A Condorcet winner is the alternative which defeats all alternatives in pairwise comparisons [14];

(b) the procedure should never choose a Condorcet loser when there is one. The Condorcet loser is the opposite of the Condorcet winner. Thus, it is an alternative that is defeated by all other alternatives in pairwise comparisons [14];

(c) the procedure makes use of the strong Condorcet criterion, which is satisfied by all systems that always end up with a strong Condorcet winner when there is one. A strong Condorcet winner is an alternative that is ranked first by all individuals [14];

(d) the procedure makes use of monotonicity. This can be expressed as "if an alternative  $x$  wins in a given profile  $P$  when a certain procedure is being applied, it should also win in the profile  $P'$  obtained from  $P$  by placing  $x$  higher in some individuals' preference rankings, *ceteris paribus*." [14]. This means that additional support cannot transform a winning alternative into a non-winning alternative;

(e) The Pareto criterion exists whenever all voters strictly prefer  $x$  to  $y$ , and thus  $y$  cannot be elected [14];

(f) the procedure presents Consistency that is satisfied by those systems that have the following property. Suppose that the group is split into two groups so that the same alternative is chosen in both groups. Then the procedure is consistent if the same alternative is chosen if the procedure is applied to the group as a whole [14];

(g) the procedure presents the Chernoff property, which means that if an alternative is a winner in a set of alternatives, it has to be the winner in every subset of these alternatives [14];

(h) the procedure is consistent with the property of independence of irrelevant alternatives. A procedure presents this property if two profiles have identical rankings over

a pair of alternatives. Thus, the collective ranking over this pair is the same in these two profiles, regardless of the rankings over the other pairs [37]; and

(i) the procedure presents the invulnerability of the no-show paradox, which is a condition in which an elector may achieve a better result by not voting, thus prompting him/her to manipulate the voting result by abstaining [14].

Several authors advocate that these characteristics are binary so that a procedure only may have one out of two conditions: either it has the property, or it does not [15]. Whenever the procedure has the property sought, it will be represented by 1 (one), and when it does not, the representation is 0 (zero). Table 1 presents the evaluation of the 12 voting procedures considered, which were evaluated by considering that the criteria of evaluation ought to be binary. It was not taken into account any criterion related to the context of the problem because any of the voting rules would receive the same information as input and would give the same type of output to the DMs. Furthermore, the hardness to implement the voting rule into the GRUS system could have been considered, but it was not evaluated the difficulties related to creating the algorithm inside the system. Therefore, only the voting properties were considered as criteria.

Voting Rule	Criteria								
	a	b	c	d	e	f	g	h	i
Amendment	1	1	1	1	0	0	0	0	0
Copeland	1	1	1	1	1	0	0	0	0
Dodgson	1	0	1	0	1	0	0	0	0
Maximin	1	0	1	1	1	0	0	0	0
Kemeny	1	1	1	1	1	0	0	0	0
Plurality	0	0	1	1	1	1	0	0	1
Borda	0	1	0	1	1	1	0	0	1
Approval Voting	0	0	0	1	0	1	1	0	1
Black	1	1	1	1	1	0	0	0	0
Plurality runoff	0	1	1	0	1	0	0	0	0
Nanson	1	1	1	0	1	0	0	0	0
Hare	0	1	1	0	1	0	0	0	0

**Table 1.** – Voting procedures vs. voting procedures

During the interview, the facilitator was seen to have a non-compensatory rationality regarding the group decision processes and, therefore, a non-compensatory method was selected to evaluate the set of alternatives. The preferences concerning the criteria were provided in order of importance to allow the weights to be calculated. The evaluation was made by considering a five-level scale as presented in Table 2 since it was not necessary to provide a complete order.

The ordinal values were converted to a numeric scale, where VU represented 0.2 on a scale from 0 to 1 and VI represented 1. This parametrization was taken into account



because a value of 0 meant that the criteria had no relevance at all for the facilitator and it would not be considered in the analysis. Since it does not make sense to consider irrelevant criteria, the least valuable criteria had to be assigned a value of 0.2. The numerical scale considered was VU=0.2, NI=0.4, SS=0.6, I=0.8, and VI=1, which are related to the levels presented in Table 2. The facilitator used this scale to evaluate each criterion and, once this step was ended, the values were normalized by considering the scaling process presented in Equation 1.

$$\pi'_i = \frac{\pi_i}{\sum_j \pi_j} \quad (1)$$

Where:  $\pi'_i$  is the scaled weight value of criterion  $i$ .

$\pi_i$  is the weight value of criterion  $i$  on the five point scale.

$\sum_j \pi_j$  is the sum of the weights of all criteria.

VU	Very Unimportant	Which means that in this context the criteria do not bring any important feature to the problem
NI	Not Important	Which means that in this context the criteria do not bring more than two important features to the problem
SS	So-so	Which means that in this context the facilitator is indifferent to the features brought by the criteria
I	Important	Which means that in this context the criteria bring at least one important feature of the problem
VI	Very Important	Which means that in this context the criteria bring more than two very important features to the problem

**Table 2.** – Voting procedures notation scale

The preferences expressed by the facilitator were related to each of the positions on the scale. Criteria c and e were considered “very important”, the former because it is imperative that the solution is in the set of non-dominated alternatives and the later because it is mandatory that the solution is Pareto-optimal. Criteria a, b and d were considered “important”: the first and the second because a procedure has to be reliable and guarantee such that the best alternative in pairwise comparison will be the winner and the worst will not, if those alternatives do exist, and the third one because additional support should not lead a winning alternative to become non-winning. No criterion was evaluated as “so-so”. The “not important” criteria were considered to be f and i, the former because the analysis will hardly ever be made considering subsets of DMs and the later because the DMs will not be able to manipulate the analysis at this point. Finally, the “very unimportant” criteria were considered to be g because it is unlikely that the group will decide to visualize a subset of alternatives during the analysis. At last, criteria h was excluded from the analysis because all procedures fail on it. It is said to be important to have a procedure that is independent of irrelevant alternatives, but none of the above are, which leads to these criteria being excluded from the analysis. As an example of the procedure to normalize the weights, let us consider criterion “a”, which

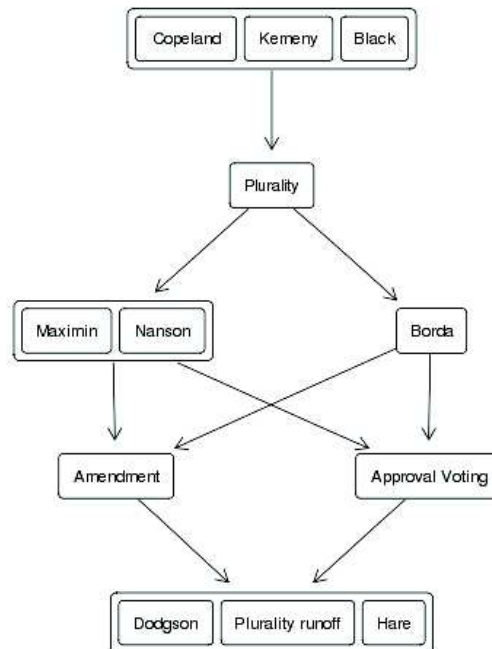
has a nominal weight of  $\pi_a = 0.80$ . The sum of all criteria is  $\sum_j \pi_j = 5.4$ . Thus,  $\pi'_a = \pi_a / \sum_j \pi_j = 0.8/5.4 = 0.148$ . The same calculations were used in all criteria and the results are presented in Table 3.

The analysis was conducted by applying two outranking procedures: ELECTRE III [3] and PROMETHEE I [4]. Two different procedures were used to allow the results from both to be compared and to verify if by changing the outranking method, this would lead the analysis to a different result.

Type of weight	Criteria							
	a	b	c	d	e	f	g	i
Scaled Weights	0.148	0.148	0.185	0.148	0.185	0.074	0.038	0.074
Weights	0.80	0.80	1.00	0.80	1.00	0.40	0.20	0.40

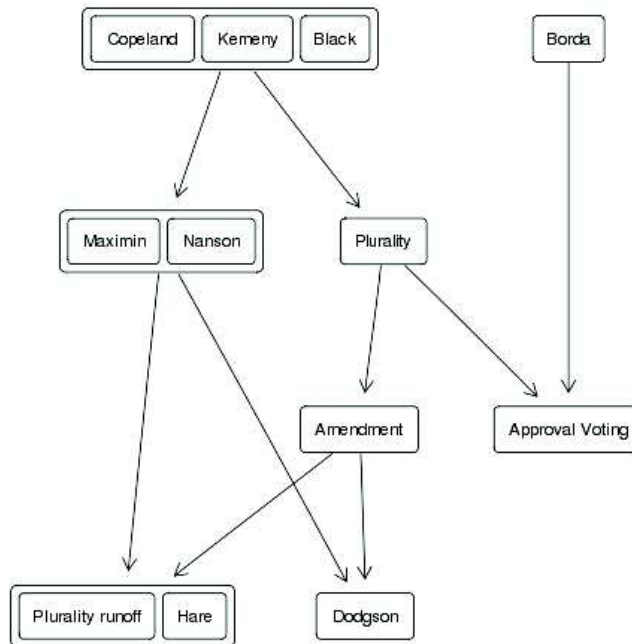
**Table 3.** – Weights of criteria

In the procedure using ELECTRE III, three concordance indices [38] were considered, namely:  $s_1 = 0.9$ ,  $s_2 = 0.85$  and  $s_3 = 0.8$ . The main idea of evaluating the data by applying different concordance indices was to verify if the kernel [3] would be modified by increasing the strength of the concordance coalition. No considerations of discordance indices were made because the values were only binary, and thus, all the differences between evaluations are 0 or 1, which enables this index to be used in this environment. In all cases, three kernels were found: (1) Copeland; (2) Black; and (3) Kemeny. The Hasse Diagram [39] presented in Figure 1 enables the relationship between all alternatives to be visualized.



**Fig. 1.** Hasse Diagram of ELECTRE III method

When PROMETHEE I was used, the Hasse Diagram presented in Figure 2 was found. The results are similar, in the sense that those based on Copeland, Kemeny, and Black were seen, once again, to have insignificant differences. This outcome is expected since the evaluation in all their criteria was the same, and the synthesis of their results was very similar. In this method, the difference was that the Borda rule was incomparable to these three rules. Thus, its position changed from third to first. In addition, when ELECTRE III method was used, the Plurality rule remained in second place, but instead of outranking Maximin and Nanson, it became incomparable. The other rules, even after undergoing some modifications as to their preference relations would not be chosen to solve the problem. The results were also compared with PROMETHEE II [4], and Copeland, Kemeny, and Black remained in the same place, but the Borda rule dropped to third.



**Fig. 2.** Hasse Diagram of PROMETHEE I method

The three methods used presented Copeland, Kemeny and Black procedures as a tie, and PROMETHEE I also presented Borda's rule as not being comparable with these voting procedures. This behavior moves the problem on to another question which is how to choose the method when such a situation arises. This indifference might have occurred due to missing criteria, thus, by considering other criteria, one could tie up the procedures. It could take into account other voting properties, the ease with which the method inside GRUS can be implemented and the possibility of adapting the procedures to a partial information environment.

The results can be easily interpreted, and the next step after choosing one of these voting rules is to create a module to work inside GRUS in order to aggregate the DMs' preference information whenever they are not interested in reaching a consensual decision. The three methods that were presented in the first position in all methods are all distance-based methods but have different types of input information and methodologies that provide DMs with a final ranking of alternatives.

## 4 Conclusion

This article has presented an application of the framework proposed by de Almeida and Nurmi [15] for choosing a voting procedure in the business context to decide which voting rule is best suited for aiding a facilitator using a GDSS called GRUS when the group does not wish to reach a consensual decision. During the application, some difficulties arose. One of them is how to go about deciding on which of the three methods to choose. Maybe the inclusion of other criteria, such as the ease of applying the rule in the decision context, may present a different solution to this problem.

In their article, de Almeida and Nurmi [15] presented their framework and suggested that the analysis of the voting procedures could be made on a five-level scale if it was decided to include a subjective criterion in the evaluation. When Nurmi [23] presented his application of this framework, he considered that all voting procedures evaluated under the voting properties only had a binary evaluation when he considered whether or not a voting procedure has a certain property. Anyhow, de Almeida and Nurmi [15] also showed that maybe this evaluation could be less strict by considering the proportion of cases where the voting procedures actually present the property. Lepelley and Valognes [26] proposed to verify the efficiency in Kim and Roush's voting procedure [28] by applying an Impartial Anonymous Culture condition (IAC) by calculating the probability of a voting situation to verify if the procedure was efficient for two voting properties: the Condorcet winner and the Condorcet loser. Fishburn and Gehrlein [25] presented a simulation to verify the efficiency of a simple majority of some voting procedures. Nurmi [27] compared distance-based voting rules in ranking environments. Therefore, in future research, it is important to run a simulation to verify the proportion in which each of these properties actually occurs in each method and to compare these with the binary results and find out if the voting rule would change in this scenario.

The choice of the method is not the only challenge the facilitator has to face in this type of aggregation. He/she must also build an agenda with the participants to decide which weight will be assigned to each of the DMs. Also, it is important to make sure the DMs want to empower the facilitator in this decision. Finally, it is important remark that the analyst must not impose their preferences in the model. This may arise ethical issue behind, particularly for the choice of the method and its parameterization.

## Acknowledgment

The authors are grateful to the Brazilian Research Council (CNPq) for their financial support of the research contained in this paper.

## References

1. Dufner, D., Hiltz, S.R., Johnson, K., Czech, R.: Distributed group support: The effects of voting Tools on group perceptions of media richness. *Group Decision and Negotiation* 4, 235–250 (1995). doi:10.1007/BF01384690.
2. Colson, G.: The OR's prize winner and the software ARGOS: how a multijudge and multicriteria ranking GDSS helps a jury to attribute a scientific award. *Computers & Operations Research* 27, 741–755 (2000). doi:10.1016/S0305-0548(99)00116-1.
3. Roy, B., Bouyssou, D.: Aide multicritère à la décision: méthodes et cas. *Economica*, Paris (1993).
4. Brans, J.P., Vincke, P., Mareschal, B.: How to select and how to rank projects: The Promethee method. *European Journal of Operational Research* 24, 228–238 (1986). doi:10.1016/0377-2217(86)90044-5.
5. Damart, S., Dias, L.C., Mousseau, V.: Supporting groups in sorting decisions: Methodology and use of a multi-criteria aggregation/disaggregation DSS. *Decision Support Systems* 43, 1464–1475 (2007). doi:10.1016/j.dss.2006.06.002.
6. Lolli, F., Ishizaka, A., Gamberini, R., Rimini, B., Messori, M.: FlowSort-GDSS – A novel group multi-criteria decision support system for sorting problems with application to FMEA. *Expert Systems with Applications* 42, 6342–6349 (2015).
7. Kim, Y., Hiltz, S.R., Turoff, M.: Coordination structures and system restrictiveness in Distributed Group Support Systems. *Group Decision and Negotiation* 11, 379–404 (2002). doi:10.1023/A:1020492305910.
8. Ackermann, F.: Participants' perceptions on the role of facilitators using Group Decision Support Systems. *Group Decision and Negotiation* 5, 93–112 (1996). doi:10.1007/BF02404178.
9. Ebadi, T., Purvis, M., Purvis, M.: A distributed and concurrent framework for facilitating cooperation in dynamic environments. In: *Proceedings - 2010 IEEE/WIC/ACM International Conference on Intelligent Agent Technology*, pp. 287–294, IAT (2010). doi:10.1109/WI-IAT.2010.260.
10. Adla, A., Zarate, P., Soubie, J.L.: A Proposal of Toolkit for GDSS Facilitators. *Group Decision and Negotiation* 20, 57–77 (2011). doi:10.1007/s10726-010-9204-8.
11. Rigopoulos, G., Karadimas, N.V., Orsoni, A.: Facilitating Group Decisions through Multicriteria Analysis and Agent Based Modeling. In: *First Asia International Conference on Modelling & Simulation (AMS'07)*, pp. 533–538 (2007). doi:10.1109/AMS.2007.40.
12. Jahng, J., Zahedi, F.: Intelligent Electronic Facilitator: Increasing GDSS Effectiveness and Making Web-Based GDSS Possible. In: *Amcis 1998*, Paper 161 (1998).
13. de Almeida, A.T., Cavalcante, C.A.V., Alencar, M.H., Ferreira, R.J.P., de Almeida-Filho, A.T., Garcez, T.V.: Multicriteria and multiobjective models for risk, reliability and maintenance decision analysis. vol. 231. Springer (2015). doi:10.1007/978-3-319-17969-8.
14. Nurmi, H.: *Voting Paradoxes and How to Deal with Them*. Springer, New York (1999). doi:10.1007/s13398-014-0173-7.2.
15. de Almeida, A.T., Nurmi, H.: A framework for aiding the choice of a voting procedure in a business decision context. In: Kamiński, B., Kersten, G.E., Szapiro, T. (eds.) *Outlooks And*

- Insights on Group Decision and Negotiation, vol. 218, pp. 211–225. Springer International Publishing, Warsaw (2015). doi:10.1007/978-3-319-19515-5\_17.
16. Gilliams, S., Raymaekers, D., Muys, B., Orshoven, J. Van: Comparing multiple criteria decision methods to extend a geographical information system on afforestation. *Computers and electronics in agriculture* 49, 142–158 (2005). doi:10.1016/j.compag.2005.02.011.
  17. Górecka, D.: On the Choice of Method in Multicriteria Decision Aiding Process. *Multiple Criteria Decision Making* 6, 81–108 (2011).
  18. Roy, B., Słowiński, R.: Questions guiding the choice of a multicriteria decision aiding method. *EURO Journal on Decision Processes* 1, 69–97 (2013). doi:10.1007/s40070-013-0004-7.
  19. Rauschmayer, F., Kavathatzopoulos, I., Kunsch, P.L., Le Menestrel, M.: Why good practice of OR is not enough-Ethical challenges for the OR practitioner. *Omega* 37, 1089–1099 (2009). doi:10.1016/j.omega.2008.12.005.
  20. Zaraté, P., Kilgour, M.D., Hipel, K.W.: Private or Common Criteria in a Multi-criteria Group Decision Support System: An Experiment. In: Yuizono, T., Ogata, H., Hoppe, U., Vassileva, J. (eds.) *Collaboration and Technology - 22nd International Conference, CRIWG 2016 Proceedings, LNCS*, vol. 9848, pp. 1-12. Springer International Publishing (2016). doi:10.1007/978-3-319-44799-5.
  21. Keeney, R.L., Raiffa, H.: *Decision with multiple objectives: preferences and value trade-offs*. John Wiley, New York (1976).
  22. Nurmi, H.: *Comparing Voting Systems*. D. Reidel Publishing Company (1987). doi:10.1007/978-94-009-3985-1.
  23. Nurmi, H.: The Choice of Voting Rules Based on Preferences over Criteria. In: Kamiński, B., Kersten, G.E., Szapiro, T. (eds.) *Outlooks And Insights on Group Decision and Negotiation*, vol. 218, pp. 241–52. Springer International Publishing, Warsaw (2015). doi:10.1007/978-3-319-19515-5\_19.
  24. Nurmi, H.: Voting Procedures: A Summary Analysis. *British Journal of Political Science* 13, 181–208 (1983). doi:10.1017/S0007123400003215.
  25. Fishburn, P.C., Gehrlein, W.W.: Majority Efficiencies for Simple Voting Procedures: Summary and Interpretation. *Theory and Decision* 14, 141–153 (1982). doi:0040-5833/82/0142-0141.
  26. Lepelley, D., Valognes, F.: On the Kim and Roush voting procedure. *Group Decision and Negotiation* 8, 109–123 (1999).
  27. Nurmi, H.: A comparison of some distance-based choice rules in ranking environments. *Theory and Decision* 57, 5–24 (2004). doi:10.1007/s11238-004-3671-9.
  28. Kim, K.H., Roush, F.W.: Statistical manipulability of social choice functions. *Group Decision and Negotiation* 5, 263–282 (1996).
  29. Saari, D.G., Merlin, V.R.: A geometric examination of Kemeny's rule. *Social Choice and Welfare* 17, 403–438 (2000). doi:10.1007/s003550050171.
  30. Borda, J.C.: *Mémoire sur les élections au scrutin*. Histoire de l'Académie Royale Des Sciences (1781).
  31. Brams, S.J., Fishburn, P.C.: Approval Voting. *American Political Science Review* 72, 831–847 (1978).
  32. Nanson, E.J.: *Methods of Election*. Transactions and Proceedings of the Royal Society of Victoria Art. XIX, 197–240 (1883).
  33. Morais, D.C., de Almeida, A.T.: Group decision making on water resources based on analysis of individual rankings. *Omega* 40, 42–52 (2012). doi:10.1016/j.omega.2011.03.005.
  34. de Almeida-Filho, A.T., Monte, M.B.S., Morais, D.C.: A voting approach applied to preventive maintenance management of a water supply system. *Group Decision and Negotiation* 26(3), 523-546 (2017). doi:10.1007/s10726-016-9512-8.

35. Cullinan, J., Hsiao, S.K., Polett, D.: A Borda count for partially ordered ballots. *Social Choice and Welfare* 42, 913–926 (2014). doi:10.1007/s00355-013-0751-1.
36. Ackerman, M., Choi, S.Y., Coughlin, P., Gottlieb, E., Wood, J.: Elections with partially ordered preferences. *Public Choice* 157, 145–168 (2013). doi:10.1007/s11127-012-9930-3.
37. Arrow, K.J.: *Social Choice and Individual Values*. 2nd edit. Wiley, New York (1963).
38. Figueira, J.R., Mousseau, V., Roy, B.: ELECTRE methods. In: Figueira, J.R., Greco, S., Ehrgott, M. (eds.) *Multiple Criteria Decision Analysis: State of the Art Surveys*, p. 133–162. Springer Science+Business Media (2005).
39. Skiena, S.: *Implementing Discrete Mathematics: Combinatorics and Graph Theory with Mathematica*. Addison-Wesley, Redwood City CA (1990).