Chapter 18
Choosing a Voting Procedure for a Group Decision Support System (GRUS)

Abstract Group Decision Support Systems (GDSS) are tools that are being increasingly used in group decision-making processes. In this context, GRUS (GRoUp Support System) is a web-based system to support group decision processes which consider the individual preferences of different actors involved in the same problem. The system supports a multicriteria approach for solving the problem. One of the ways to aggregate individual preferences is by using a voting procedure. This Chapter presents how the framework for choosing a Voting Procedure can be implemented in this GRUS System in order to facilitate this process. Two different situations for applying the framework are considered. In the first one, the users evaluate the problem and apply the framework for choosing a voting procedure. In the second situation, the result of the framework applied with an expert is presented for the users as a generic voting procedure to aggregate the individual rankings of the decision-makers.

18.1 GRoUp Support System (GRUS)

In many organizations, where collective decisions should be made, it is common to have conflict situations due to decision-makers (DMs) having different points of view and interests from each other. Furthermore, many managers spend their productive time (between 25 and 80%) in meetings at which decisions are made, but approximately 50% of this time is wasted as a result of information being lost or distorted (Dufner et al. 1995). Therefore, in order to reduce such losses and raise the productivity of managers, several Group Decision Support Systems (GDSS) have been proposed in the literature (Colson 2000; Damart et al. 2007; Adla et al. 2011; Lolli et al. 2015).

GDSS are often built based on computer platforms with a formal framework that uses a multi-criteria approach to help DMs express and evaluate their preferences and the parameters that will be used. Thus, Zaraté et al. (2016) built a GDSS on a web-based platform, called GRoUp Support System (GRUS), which is free and available upon request at http://www.irit.fr/GRUS.

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GRUS presents services commonly available in GDSS, such as the definition/design of a static or dynamic group decision process, the management of collaborative tools (add, modify, delete), and the management of automatic reporting such as PDF files (Zaraté et al. 2016). This system aids the conduct of meetings which may be synchronous or asynchronous, and distributed or face-to-face. The users of such a system are DMs and the facilitator. It is modularized to allow the facilitator to build a structure that best fits the problem. The facilitator is also responsible for managing the process of how the DMs interact with each other. The DMs should describe their points of view and ideas, whether anonymously or not, in the step called brainstorming as to the electronic interaction. They suggest the criteria and alternatives related to the problem to be solved, and then give their assessment of each alternative on each criterion, thereby generating a consequence matrix.

For the evaluations, the DMs indicate their preferred weights for the criteria, and enter a suitability equation function, thereby defining their interpretation of each criterion. In order to calculate the score of each alternative, two aggregation techniques are implemented in the GRUS: The Simple Additive Weight (SAW) (Keeney and Raiffa 1976) and the Choquet Integral (Ebadi et al. 2010).

The final decision must be managed by a facilitator who does so with a consensus process that is conducted in a face-to-face group meeting. Sometimes this process requires DMs to change their positions with regard to how to solve the problem until a potential compromise is found. This is usually time-consuming especially when the DMs have different objectives regarding the same problem. Therefore, the concern that is raised here is how to deal with this process when the DMs have different objectives.

De Almeida et al. (2015) noted that when DMs have divergent opinions regarding the objectives, it is necessary to work with their individual rankings of the alternatives and aggregate them in order to reach final choices that they can agree to. One way to deal with this type of aggregation is to use a voting procedure (VP). In this case, it is usually the facilitator who is responsible for choosing a VP compatible with the DMs´ needs so as to reach a group decision.

Numerous VPs have been studied over the years that have been applied in different situations. A comparative analysis of some of these VPs is given in Nurmi (1999), who showed that each procedure is associated with advantages and disadvantages and seeks to avoid different voting paradoxes. Nevertheless, the definition of the best VP usually depends on the properties of each procedure, which have been discussed over the years in the literature (Nurmi 2015) besides which many authors have compared VPs by considering their properties (Nurmi 1983, 2004; Fishburn and Gehrlein 1982; Lepelley and Valognes 1999; Kim and Roush 1996; Kim et al. 2002).

Bearing this in mind, according to de Almeida and Nurmi (2015), in specific situations, the facilitator is perhaps not the best person to conduct this task of choosing a VP, since he/she will not deal with the consequences of the social choice. Thus, the framework for choosing a VP that is applied here to aid this choice allows the DMs to have their preferences considered in this analysis.

The main idea of this framework is to consider a decision matrix where the VPs are the alternatives which are evaluated regarding some criteria (that are voting properties, which are characterized by the ability of a procedure to overcome voting paradoxes, and are related to the context of the problem, by considering how easily this matrix can be applied). A multicriteria approach is used to evaluate this decision matrix, which considers the characteristics of the methods and the problem itself (de Almeida et al. 2015).

In this Chapter, two situations for applying this framework for choosing a VP are considered:

Situation 1: In order to aid the users choosing a VP. In this case, the framework for choosing a VP is implemented in the GRUS and it is applied when the users are willing to choose a VP so as to make an in-depth evaluation of the characteristics of the problem and the advantages and disadvantages of the voting procedures for the specific case.

Situation 2: In order to indicate generically a voting procedure for the GDSS. In this case, the users are not willing to choose a specific VP, or do not have enough information regarding voting properties. Thus, the framework for choosing a VP is applied with an expert in voting rules who will make a holistic evaluation of the properties, yet thinking about the information that the GRUS is providing as individual rankings. The VP chosen by this expert will be implemented in the GDSS as a suggestion for an aggregation procedure that will result in a final recommendation being made.

Figure 18.1 shows the flowchart for applying the framework for choosing a VP to be included in the GRUS.

18.2 Structuring the Problem

The problem will be structured predominantly in the same way for both situations. In order to evaluate the voting procedures, the voting properties will be considered as criteria, which are presented as follows (Palha et al. 2017; Nurmi 1999; Arrow 1963; Felsenthal and Nurmi 2018):

- Condorcet winner: evaluates if the procedure chooses a Condorcet winner when there is one, i.e., the alternative which defeats all alternatives in pairwise comparisons.
- Condorcet loser: evaluates if the procedure does not choose a Condorcet loser when there is one, i.e., the alternative which is defeated by all other alternatives in pairwise comparisons.
- Strong Condorcet: evaluates if the procedure ends up with a strong Condorcet winner when there is one, i.e., the alternative which is ranked first by most individuals.
- Monotonicity: evaluates if the procedure displays monotonicity, i.e., "if an alternative y wins in a given profile P when a certain VP is being applied, it should also win in the profile P' obtained from P by placing y higher in some individuals' preference rankings" (Nurmi 1999). This means that additional support cannot transform a winning alternative into a non-winning alternative.

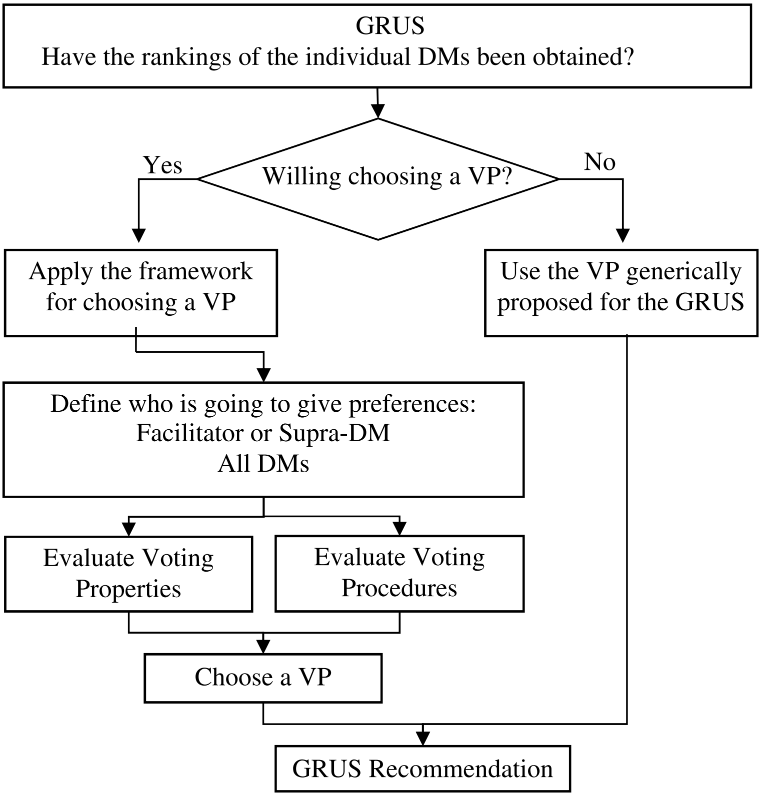

Fig. 18.1 Flowchart of the GRUS incorporating the framework for choosing a VP

- Pareto: evaluates if the procedure has a collective rationality, i.e., whenever all individuals strictly prefer x to y, then y is not chosen.
- Consistency: evaluates if the procedure satisfies the condition of the invariance of the set chosen when different decision-making groups are gathered together to make social choices. Suppose a group is divided into two groups and applies a voting procedure, which results in the same alternative being chosen by both subgroups. Then the procedure is consistent if the same alternative is chosen when the procedure is applied to the group as a whole.
- Chernoff: evaluates if the procedure presents the Chernoff property, i.e., if an alternative is a winner in a set of alternatives, it must be the winner in every subset of these alternatives.
- Independence of irrelevant alternatives: evaluates if the procedure satisfies this property, i.e., a procedure satisfies the condition of the independence of irrelevant alternatives, if, whenever two profiles have identical rankings over a pair of alternatives, the collective ranking over these two alternatives is the same in the two profiles, regardless of the rankings over the other pairs.

– Invulnerability of the no-show paradox: evaluates if the procedure satisfies this property, i.e., if a DM may achieve a better result by not voting, thus prompting him/her to manipulate the voting result by abstaining.

Many authors consider that the voting procedures can be evaluated regarding these criteria (or characteristics) by a binary evaluation, so a procedure either satisfies or does not satisfies the property (de Almeida and Nurmi 2015). Whenever the procedure satisfies the property sought, it will be represented by 1 (one), and when it does not, the representation is 0 (zero).

Note that consideration was not given to any criterion related to the context of the problem since any of the voting procedures would then receive the same input and would give the same output to the DMs. Moreover, the difficulties related to creating the algorithm within the system and to executing it in the GRUS system were not evaluated. Therefore, only the voting properties were considered as criteria.

The subset of voting procedures considered in this analysis were: Amendment, Copeland, Dodgson, Maxmin, Kemeny, Plurality, Borda, Approval Voting, Black, Plurality runoff, Nanson and Hare (Borda 1781; Brams and Fishburn 1978, Nanson 1883; Nurmi 1987, 1999; Saari and Merlin 2000; Felsenthal and Nurmi 2018). There are other methods available but these were not considered here. These include those that consider partial information (Cullinan et al. 2014; Ackerman et al. 2013) and the quartiles method (Morais and de Almeida 2012; de Almeida-Filho et al. 2017).

The binary evaluation of the VP considered regarding the voting properties is shown in Table 18.1. Note that the criterion of the independence of irrelevant alternatives has been excluded from the table since none of the voting procedures considered satisfies this property, so it does not make sense to consider this criterion in this case. It is important to have a procedure that is independent of irrelevant alternatives, but none of the voting procedures considered are, which leads to these criteria being excluded from the analysis.

As to a non-compensatory rationality to evaluate this set of VPs, a non-compensatory multicriteria method should be selected. In order to establish the relative importance of the weights of the criteria, this can be evaluated by considering a five-level scale as presented in Table 18.2.

As can be observed, the verbal scale was converted to a numeric scale. It is worth noting that this parametrization begins with 0.20. Since the value of 0 meant that the criterion had no relevance at all for the user, it was not considered in the analysis.

The user should use this scale to evaluate each criterion and, after this step has ended, the values should be normalized by considering the scaling process presented in the Equation (Palha et al. 2017):

$$\pi_i' = \frac{\pi_i}{\sum_j \pi_j}$$

where: π'_i is the value of the scaled weight of criterion i.

π_i is the value of the weight of criterion i on the five point scale.

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

Table 18.1 Consequence matrix for discrete binary outcome

	Criteria							
Voting procedure	Condorcet winner	Condorcet loser	Strong condorcet	Mono-tonicity	Pareto	Consistency	Chernoff	Invulnerability to the no-show paradox
Amendment	1	1	1	1	0	0	0	0
Copeland	1	1	1	1	1	0	0	0
Dogson	1	0	1	0	1	0	0	0
Maxmin	1	0	1	1	1	0	0	0
Kemeny	1	1	1	1	1	0	0	0
Plurality	0	0	1	1	1	1	0	1
Borda	0	1	0	1	1	1	0	1
Approval	0	0	0	1	0	1	1	1
Black	1	1	1	1	1	0	0	0
Pl. runoff	0	1	1	0	1	0	0	0
Nanson	1	1	1	0	1	0	0	0
Hare	0	1	1	0	1	0	0	0

Table 18.2 Notation scale for voting properties

Verbal scale	Notation	Numerical scale	Description
Very unimportant	VU	0.20	In this context, the criteria do not add any important feature to the problem
Not important	NI	0.40	In this context, the criteria do not add more than two important features to the problem
So-so	SS	0.60	In this context, the user is indifferent to the features added by the criteria
Important	I	0.80	In this context, the criteria add at least one important feature to the problem
Very important	VI	1.00	In this context, the criteria add more than two important features to the problem

Adapted from Palha et al. (2017)

18.2.1 Situation 1

In this situation, the users of the GRUS are willing to apply the framework to choose a Voting Procedure, since they have knowledge about the criteria considered to evaluate the VPs. Thus, in order to evaluate the preferences regarding the voting proprieties, it is necessary to establish who will define the required parameters of the multicriteria approach. For this task, three possibilities are considered:

– The facilitator will give his/her preferences, thereby allowing him/her to decide which VP would be best suited for the problem to be solved.
– The Supra-Decision-Maker will give his/her preferences if the problem has one and he/she would like to express his/her opinion instead of leaving the facilitator to do so.
– The DMs give their preferences by achieving an agreement as to the voting properties.

Although there are three possibilities to consider who will give the preference parameters regarding the voting properties, once the framework for choosing a VP is established, it will run in the same way, independently.

Thus, this situation will be illustrated based on the application presented by Palha et al. (2017), where one of the authors plays the role of the facilitator.

The facilitator considered using all the voting procedures available in the GRUS system, which were: Amendment, Copeland, Dodgson, Maxmin, Kemeny, Plurality, Borda, Approval Voting, Black, Plurality runoff, Nanson and Hare.

Therefore, her preferences were elicited by an interview regarding the voting procedure to be analyzed in order to aggregate the rankings of the group members. Thus, the facilitator expressed her preferences regarding the voting properties in accordance with Table 18.2. Table 18.3 presents the facilitator's preferences and the respective scaled weights.

Table 18.3 Preferences of the facilitator using the scale to evaluate the voting properties

Voting proprieties	Verbal scale	Numerical scale	Scaled weights
Condorcet winner	I	0.80	0.148
Condorcet loser	I	0.80	0.148
Strong Condorcet	VI	1.00	0.185
Monotonicity	I	0.80	0.148
Pareto	VI	1.00	0.185
Consistency	NI	0.40	0.074
Chernoff	VU	0.20	0.038
Invulnerability to the no-show paradox	NI	0.40	0.074
Total		5.40	1.00

As can be observed in Table 18.3, the criteria considered VI (Very Important) were Strong Condorcet and Pareto. The facilitator argued that the solution must be in the set of non-dominated alternatives and also Pareto-optimal.

The criteria considered I (Important) were Condorcet winner, Condorcet loser and Monotonicity. The facilitator stated that the procedure should be reliable, and it is important to guarantee that the best alternative in a pairwise comparison will be the Condorcet winner and the worst will not, if there these alternatives. Moreover, additional support should not lead a winning alternative to become a non-winning one.

The criteria of consistency and invulnerability were evaluated as NI (Not Important), since the analysis will hardly ever be made considering subsets of DMs, and the DMs will not be able to manipulate the analysis at this point.

Finally, the Chernoff criterion was considered VU (Very Unimportant) because it is unlikely that the group will decide to visualize a subset of alternatives during the analysis.

The scaled weights were calculated by normalization i.e., by dividing the nominal weight by the sum of all criteria (total). For example, the Condorcet winner has a nominal weight of π a = 0.80, being the sum of all criteria Σj π j = 5.4, thus, π' a = π a/Σj πj = 0.8/5.4 = 0.148. The same calculations were used in all criteria and the results are presented in Table 18.3.

With the consequence matrix (as presented in Table 14.1—Chap. 14) and the weights, the analysis was conducted by applying ELECTRE III (Roy and Bouyssou 1993; Roy and Słowiński 2013). This multicriteria outranking method is based on comparisons between alternatives. It aims to eliminate the least advantageous and to indicate the most preferred action as determined by most of the criteria (Roy 1996). This method introduces concepts of preference p_j and indifference q_j to each criterion g_j. Consequently, the DM should establish a range of values in which one action is strictly preferable to another, and a range in which one action is indifferent.

Then, the facilitator considered three concordance indices (Figueira et al. 2005): s1 = 0.9, s2 = 0.85 and s3 = 0.8. The objective of applying different concordance indices was to verify if the kernel (Roy and Bouyssou 1993) would be altered if the strength of the concordance coalition is increased. Since the values were only binary, i.e., all the differences between evaluations are 0 or 1, discordance indices were not considered. Thus, the result indicates three voting procedures in the kernel (Copeland; Kemeny and Black). Figure 18.2 presents the result and the relationship between all alternatives.

In order to compare this result with other outranking multicriteria methods, and also to verify if changing the method would modify the result, PROMETHEE I (Brans et al. 1986) was also applied. This method provides a partial ranking based on pairwise comparisons. It considers six preference functions to evaluate criteria, and does so by considering the deviation between the evaluations of two alternatives on a particular criterion. For small deviations, the DM will allocate a small preference to the best alternative and even possibly no preference, if the DM considers that this deviation is

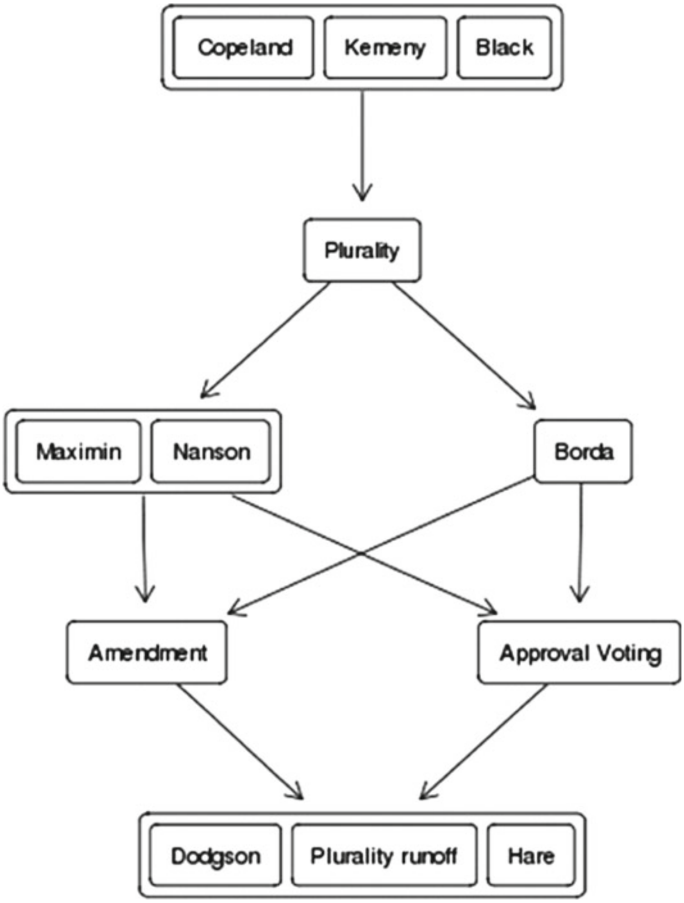

Fig. 18.2 Result of ELECTRE III. *Source* Palha et al. (2017)

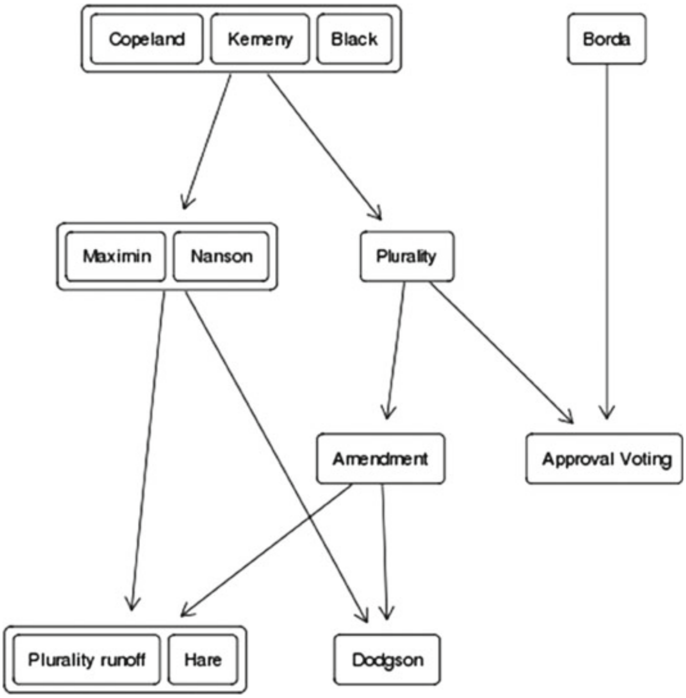

Fig. 18.3 Result of PROMETHEE I. *Source* Palha et al. (2017)

negligible. The larger the deviation, the stronger the preference. For this case, where only binary performance was considered, the usual preference function was used. This function means that any difference between the performance of alternatives will be strictly preferred. Figure 18.3 shows the result of applying PROMETHEE I.

As can be seen, the result found by applying PROMETHEE I was like that found from ELECTRE III, and the voting procedures Copeland, Kemeny and Black were, once again, found to have no differences. In fact, this outcome was expected since the evaluation of these alternatives was the same in all criteria. The difference when applying PROMETHEE I that can be highlighted is that Borda was not comparable to these three procedures. Thus, its position changed from third to first. Besides, Plurality remained in second position in both methods. However, while Maximin and Nanson were placed third by ELECTRE III, using PROMETHEE I, they were placed second but were not comparable with Plurality.

To sum up, on applying the two multicriteria methods, the voting procedures Copeland, Kemeny and Black are presented as a tie, and PROMETHEE I also presented Borda's rule as not being comparable with these voting procedures.

This performance links the problem to another concern which is: how should the voting procedure be chosen when the result of the framework for choosing a VP is a tie? This situation might occur because some criteria are missing. Thus,

Table 18.4 The expert's preferences on using the Scale to evaluate the voting properties

Voting proprieties	Verbal scale	Numerical scale	Scaled weights
Condorcet winner	I	0.80	0.133
Condorcet loser	I	0.80	0.133
Strong Condorcet	VI	1.00	0.167
Monotonicity	SS	0.60	0.100
Pareto	VI	1.00	0.167
Consistency	VI	1.00	0.167
Invulnerability to the no-show paradox	I	0.80	0.133
Total		6.00	1.00

by considering other criteria, the tie between these procedures could be broken. Other voting properties could be considered e.g., the possibility of adapting the procedures to a partial information environment. Or even using the three procedures and discussing the results that these achieve.

It is worth noting that Copeland, Kemeny and Black are all distance-based procedures, and although they have the same type of input information, they have different algorithms that can provide DMs with a final ranking of alternatives.

18.2.2 Situation 2

In this situation, the users of the GRUS are not willing, or do not have enough information, to decide which voting procedure best fits the problem. They would simply like to know the final recommendation since they have already given their preferences regarding the alternatives and the criteria of the problem studied. Therefore, they have the individual DMs' rankings.

For this situation, the framework for choosing a Voting Procedure was applied with an expert, who in this case was one of the authors of this book who played the role of the expert, in order to make a generic recommendation for a voting procedure for the GRUS.

The expert of voting rules made a holistic evaluation of the properties, while taking into account the information that the GRUS provided as individual rankings.

Based on that perspective, the subset of voting procedures that the expert considered was: Copeland, Dodgson, Maxmin, Borda, Nanson and Hare.

Considering these voting procedures, it makes no sense to evaluate the voting properties of Chernoff and of the Independence of irrelevant alternatives, since all VPs considered fail in these criteria. The consequence matrix (VP x properties) considered for discrete binary outcome is presented in Table 14.1 (Chap. 14). And the decision matrix uses the value function in Eq. 14.1 (Chap. 14).

Table 18.4 shows the expert's preferences on using the Scale for evaluating the

Table 18.5 Result of applying the PROMETHEE II method

Rank	VP	Phi	Phi+	Phi−
1	Borda	0.1398	0.4132	0.2734
2	Copeland	0.1398	0.1998	0.06
3	Nanson	0.0198	0.1398	0.12
4	Maximin	−0.0198	0.1466	0.1664
5	Dodgson	−0.1398	0.0866	0.2264
6	Hare	−0.1398	0.0866	0.2264

voting properties, as proposed in Table 18.2.

After applying the PROMETHEE II method, which is similar to an additive method in this case of using the binary performance of the alternatives, the result achieved is shown in Table 18.5.

The Borda procedure, the VP chosen by this expert, could be implemented in the GDSS as a suggestion for an aggregation procedure to give a final recommendation.

18.3 Topics for Further Reflection

This chapter presented how the framework for choosing a voting procedure could be implemented in the GRUS GDSS when the group does not wish to reach a consensual decision. In this case, the group can proceed to use the framework itself or the group can use a generic voting procedure chosen by an expert using the framework.

It is important to note that applying the framework avoids it being manipulated on behalf of one or more parties, even when it is applied considering the facilitator's preferences.

18.4 Suggestions for Reading

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