The GDSS PROMETHEE Procedure

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ABSTRACT. *An original procedure for group decision support is proposed. Three stages are considered. A preliminary stage takes care of structuring the group decision problem in a multicriteria form. An individual evaluation stage then provides each decision-maker with a way to express his personal preferences and to analyze the resulting data using the PROMETHEE multicriteria methodology. Finally, a global evaluation stage emphasizes the best consensus decisions as well as the possible conflicts among the decision-makers. The PROMETHEE and GAIA methods are extended for this purpose. The whole procedure is designed to take place in a computerized decision room, under the control of a facilitator.*

RÉSUMÉ. *Une approche originale d'aide à la décision de groupe est proposée. Elle comporte trois étapes. La première étape (étape préliminaire) a pour objectif de structurer le problème de décision de groupe sous forme multicritère. Une étape d'évaluation individuelle permet ensuite à chaque décideur d'exprimer ses préférences personnelles et d'analyser ses données à l'aide de la méthodologie multicritère PROMETHEE. Enfin, l'étape d'évaluation globale met en évidence les solutions de meilleur consensus ainsi que les éventuels conflits entre décideurs. Pour ce faire, des versions adaptées des méthodes PROMETHEE et GAIA sont décrites. La procédure proposée est conçue de façon à se dérouler dans une salle de décision informatisée, sous la direction d'un facilitateur.*

KEYWORDS: *multicriteria decision aid, group decision support system, PROMETHEE methods.*

MOTS-CLÉS : *aide à la décision multicritère, système d'aide à la décision de groupe, méthodes PROMETHEE.*

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1. Introduction

Most decision problems involve several responsible decision-makers. They can for instance represent different departments of a firm, or different countries in an international organization, or simply different partners involved in a project. Each decision-maker usually has his or her own specific objectives. Although these individual objectives are often strongly conflicting, a consensual decision must be reached. This is not an easy problem.

Since the beginning of the eighties several GDSS (Group Decision Support Systems) were developed to assist decision-makers in such a context. For an overview of the corresponding methodologies, see for example [IZ 92], [BEL 96]. While many current GDSS focus on ideas structuring, alternative generation and voting procedures, relatively few are using multicriteria decision aid for group decision support. In this paper we propose such an original multicriteria group decision methodology based on the PROMETHEE and GAIA methods. The procedure is designed to take place in a computer-equipped GDSS room and to be conducted by a facilitator.

In a preliminary stage the facilitator helps the decision-makers to generate a stable set of alternatives and a set of evaluation criteria. 'Open-discussion' phases alternate with pure 'computer' ones.

A first individual evaluation stage then takes place. Each decision-maker investigates the alternatives through his own objectives. PROMETHEE provides him with rankings of the alternatives and GAIA with a graphical representation of the decision problem. Extensive sensitivity analyses are possible.

In the second, global, evaluation stage, the points of view of all the decision-makers are compared. A global consensus solution is proposed by PROMETHEE while GAIA is used to identify the potential conflicts between decision-makers. A sensitivity analysis based on the weighting of the decision-makers is then possible. Additional suggestions and feedback can be proposed for resolving the conflicts.

The complete procedure is described in 11 steps. It is, however, flexible and alternative approaches can be considered by the facilitator according to the characteristics of each actual decision problem.

A comprehensive application, using the GDSS-PROMETHEE software, is described to illustrate this procedure.

2. The GDSS-PROMETHEE room

The decision-makers are meeting together with the facilitator in the GDSS-PROMETHEE decision room. The role of the facilitator is to conduct the meeting according to the GDSS-PROMETHEE procedure, to moderate direct discussions between decision-makers and to assist the group in order to obtain good consensual decisions as efficiently as possible.

The GDSS-PROMETHEE room is a classical GDSS room where the GDSS-PROMETHEE software has been installed. It contains R decision-makers stations. Each station is designed for a single decision-maker possibly accompanied by one or two assistants. All the stations are equipped with a personal computer and possibly with fax and telephone connections to allow the decision-makers to keep in touch with their operational base or to obtain additional data (see Figure 1).

All the individual stations are connected to the computer of the facilitator through a local area network. Overhead projectors, a LCD projector and white boards are also available to the facilitator in order to display information to the whole group. A printer can be used to provide quickly the minutes of the meeting. The whole installation can be either fixed or portable, using notebook computers.

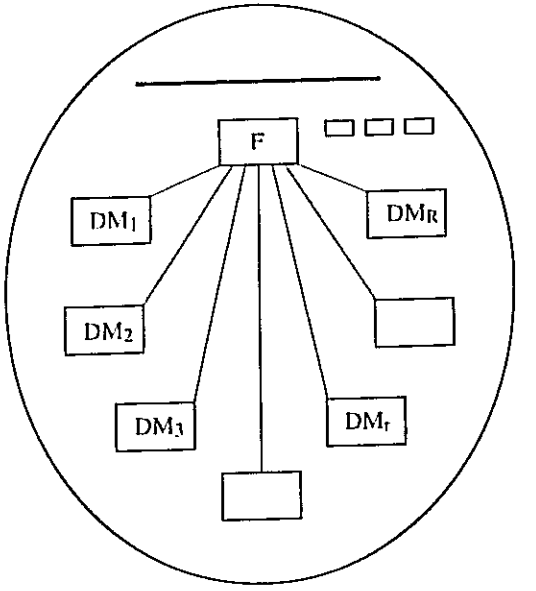


Figure 1. *GDSS-PROMETHEE room*

The human aspects of group decision making cannot be replaced by a completely computerized procedure. Eye-contact, for instance, can be decisive in some situations. Rather than simple replacements for traditional group decision meetings, GDSS's must therefore be considered as complements, providing the group decision process with additional information and enhanced efficiency. For this reason, the GDSS-PROMETHEE methodology alternates both 'computer' phases and 'open-discussion' phases. This is possible not only in a GDSS room but also when decision-makers are located in different places. A Java-based version of the GDSS-PROMETHEE program has been developed for this purpose. It can be used on Internet or on an Intranet network. In this case 'open-discussion' phases would be held through videoconference sessions.

3. Preliminary stage-structuring the decision problem

The preliminary stage is a phase of knowledge acquisition and problem structuring. Its purpose is to build an evaluation table, as displayed in Figure 3, that includes a set of potential alternative decisions and a set of criteria through which they will be evaluated.

A facilitator has first to be appointed. For a comprehensive list of the qualities that are required from a facilitator, see, for instance, [VEN 96, p.145]. On one hand, the facilitator has to be familiar with the GDSS-PROMETHEE methodology and the underlying multicriteria decision aid methods, and on the other hand he needs to have a reasonable knowledge of the actual group decision problem and its context (company or organization structure,...). The facilitator plays a crucial role. He is responsible for conducting the discussions and progressively structuring the decision problem. At this stage, the procedure is extremely flexible. Individual opinions can be expressed freely, feedback is possible at any time, additional steps can be considered, and some other deleted.

The following steps can be considered potentially.

Step 1. First contact facilitator – Decision-Makers. It is recommended to hold at least one preliminary meeting in order to ensure contact between the facilitator, the decision-makers and, possibly, between some experts involved in the decision process. This can take place out of the GDSS-PROMETHEE room. According to the characteristics of the decision problem, the facilitator can meet the decision-makers and the experts either together or individually. Each decision-maker is encouraged to express his own opinions in order to progressively enrich the maturity of the facilitator with respect to the decision process.

Step 2. Problem desciption. The decision-makers meet in the GDSS-PROMETHEE room. The facilitator comments the available infrastructure and gives

an overall description of the problem according to the information he has collected during Step 1.

Step 3. Alternative generation. This is a 'computer' phase during which the decision-makers work separately. All the decision-makers are invited to formulate possible alternatives using their computer stations. For this purpose they use a specific entry form as shown in Figure 2.

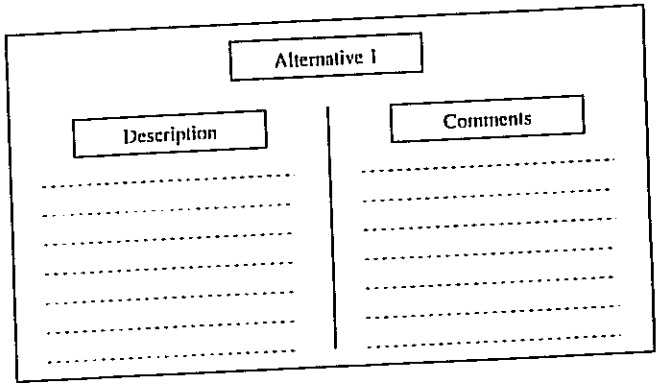


Figure 2. *Alternative generation form*

After giving a name to his proposal, the decision-maker fills in the left-hand side column as complete as with a possible description of the alternative. Each decision-maker may introduce one or more proposals. The nature of the alternatives depends of course on the nature of the decision problem. One can imagine:

- EQuipment,
- Marketing Strategies,
- R&D Projects,
- Production Schemes,
- Long Term Strategies,
- Macroeconomic Policies, etc.

A limited period of time will be allocated for this step. The procedure is more efficient than a traditional 'open-discussion' because all the decision-makers are working at the same time, each can concentrate on and express freely his own proposals. Nobody is disturbed by objections, other proposals and various comments. An important number of alternatives can be generated and described in a limited period of time.

Step 4. Stable set of alternatives. When the time allocated for the alternative generation is over, all the proposals are automatically collected by the facilitator on his own computer and can be displayed one by one to the audience. The process can

take place either anonymously or not. In many situations, the decision-makers can prefer to remain anonymous, in order for instance to avoid direct conflicts with colleagues. This step is an 'open-discussion' phase. No information is entered on the computers. Each decision-maker discovers the proposals introduced by his colleagues and listens to the comments. The group acquires a global view of the proposed solutions. The facilitator has to be particularly active in order to stimulate comments from the decision-makers and to help them to combine possible proposals, to consider new ones or to eliminate others when they are unanimously considered as non-realistic. The step ends when a stable set of alternatives is defined. However, the procedure remains flexible as additional alternatives can always be considered later on by cycling back to Step 3.

Step 5. Comments on the alternatives. This is again a 'computer' phase. All the alternatives obtained at the end of the previous step are transmitted by the facilitator to the individual work stations of the decision-makers. They now have the opportunity to enter their comments and objections in the right hand side of the alternative generation form. The decision-makers are working in parallel so that a large set of details can be obtained in a limited amount of time. All the comments are then collected by the facilitator and forwarded to each participant so that nothing gets lost for possible further use.

Step 6. Evaluation criteria. After having collected information on the possible alternatives, the problem of selecting the best one(s) has to be faced by the group. Usually there is no unanimity on the best solutions because the decision-makers have different preferences. On one hand each decision-maker is facing individual conflicts, because of the multicriteria nature of the selection problem, and on the other hand there are conflicts between the decision-makers themselves. The GDSS-PROMETHEE procedure will now help the group to manage these conflicts.

For this purpose, an 'open-discussion' phase now takes place to define the possible evaluation criteria. A similar procedure can be followed as for the generation of the alternatives. Common and individual criteria can be considered. The common criteria are those that are agreed upon by all the decision-makers. For instance cost, production and manpower are likely to be common criteria for equipment acquisition problems. Individual criteria can be considered by one or several decision-makers and not necessarily by the whole group. For instance, the security manager of a factory will not consider the same evaluation criteria as the financial manager.

All the criteria, common ones as well as individual ones, are collected by the facilitator and presented in an evaluation table similar to that of Figure 3 (the two first rows of the table correspond to preference data required by the PROMETHEE methods; their exact meaning will be explained later). This evaluation table is then transmitted to all the decision-makers.

Those criteria for which objective data exist can be evaluated directly by the facilitator. The information necessary to evaluate the other criteria has also to be collected on the basis of the advice of the decision-makers.

All the decision-makers are thus facing the same evaluation table including n possible alternatives and k evaluation criteria. Each decision-maker can enter, if requested, his own evaluations in the table. This step ends the preliminary stage and the next evaluation stages can start.

Pref. fcts.	$P_1(...)$	$P_2(...)$	...	$P_j(...)$	...	$P_k(...)$
Weigh TS	w_1	w_2	...	w_j	...	w_k
	$f_1(.)$	$f_2(.)$	...	$f_j(.)$	...	$f_k(.)$
a_1	$f_1(a_1)$	$f_2(a_1)$	...	$f_j(a_1)$	...	$f_k(a_1)$
a_2	$f_1(a_2)$	$f_2(a_2)$	...	$f_j(a_2)$	...	$f_k(a_2)$
...	...	...	...	...	...	...
a_i	$f_1(a_i)$	$f_2(a_i)$	...	$f_j(a_i)$	...	$f_k(a_i)$
...	...	...	...	...	...	...
a_n	$f_1(a_n)$	$f_2(a_n)$	...	$f_j(a_n)$	...	$f_k(a_n)$

Figure 3. *Evaluation table*

As mentioned previously, the various steps of the preliminary stage are provided as guidelines to start the procedure and to reach a good basic structuring of the decision problem. If, from the beginning, the problem is sufficiently structured so that alternatives and criteria are well defined, all these steps are not needed and the evaluation stages can start immediately. However, this is not often the case and it will usually be necessary to go through all these steps. It is even recommended to run them twice, or even more, so that all the new ideas coming up in the discussions can be taken into account. Alternatively, for poorly structured problems, a more extended discussion and brainstorming procedure, based on the Delphi-method, can be used (cf. [KEN 95]).

As with most multicriteria decision aid methods, the PROMETHEE methods request numerical evaluations. Qualitative scales (such as: very good, good, average, bad, very bad) will have to be transformed into numerical ones (such as: 5, 4, 3, 2, 1 or a more sensitive scale from 0 to 10 or 0 to 100).

All the evaluations are expressed in their own units. For instance: US$ for costs, tons for production, number of people for manpower... All scale effects are completely taken into account by the PROMETHEE methods.

4. Individual evaluation stage

The proposed alternatives must now be evaluated. The GDSS-PROMETHEE procedure includes an individual evaluation stage which is performed by each decision-maker separately and a global one for the whole group.

Once the alternatives and the evaluation criteria have been identified, the evaluation process can start. For this purpose the basic PROMETHEE methodology is used. Each decision-maker therefore first needs to define additional information: information between the criteria which will be given by weights of relative importance and information within the criteria which will be given by preference functions.

Step 7. Weights of the criteria

Let $DM_r(r = 1,2,\ldots R)$ be the R decision makers and

$$w_1^r, w_2^r, \ldots w_j^r, \ldots w_k^r \qquad \left(\sum_{j=1}^{k} w_j^r = 1\right) \qquad [4.1]$$

the weights associated to the k criteria by DM_r. There is no objection to consider normed weights.

If decision-maker DM_r considers that some criteria are not relevant to him, he will assess weights equal to zero to these criteria. This means that these criteria will not be considered in his personal analysis. Consequently, although every decision-maker is facing the same evaluation table, the number of active criteria considered by each of them can vary.

Step 8. Preference functions. According to the PROMETHEE procedure, a preference function must be associated to each criterion for pairwise comparisons. Let

$$P_j(a,b) = G_j\left[f_j(a) - f_j(b)\right] \qquad [4.2]$$

$$0 \le P_j(a,b) \le 1 \qquad [4.3]$$

be the preference function associated to criterion $f_j(.)$, where G_j is a non decreasing function of the deviation between $f_j(a)$ and $f_j(b)$. If $f_j(.)$ is a criterion to be maximized, we will have:

$$\begin{cases} G_j\left[f_j(a) - f_j(b)\right] = 0 & \text{if} \quad f_j(a) < f_j(b) \quad \textit{no preference} \\ G_j\left[f_j(a) - f_j(b)\right] \sim 0 & \text{if} \quad f_j(a) > f_j(b) \quad \textit{weak preference} \\ G_j\left[f_j(a) - f_j(b)\right] \sim 1 & \text{if} \quad f_j(a) >> f_j(b) \quad \textit{strong preference} \\ G_j\left[f_j(a) - f_j(b)\right] = 1 & \text{if} \quad f_j(a) >>> f_j(b) \quad \textit{strict preference} \end{cases} \qquad [4.4]$$

The preference functions allow to translate the deviations observed on a specific criterion into degrees of preference independent of its scale as shown in Figure 4.

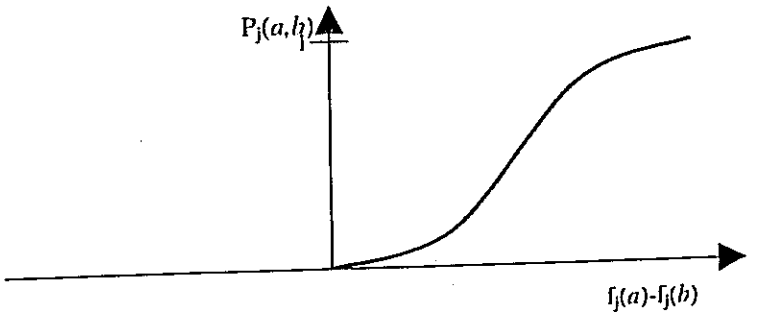


Figure 4. *Preference function*

In order to facilitate the selection of preference functions, six basic types have been proposed (cf [BRA 82], [BRA 85], [BRA 94]). In each case the preference function depends maximum on two parameters, with a clear economical significance (indifference and/or preference thresholds).

In this step, the facilitator helps the decision-makers to select the preference functions. As each decision-maker is facing the same criteria (although the associated weights could be different), the selection of the preference functions can take place globally in an 'open-discussion' phase. In this case, all the preference functions will be the same for all decision-makers. There is, however, no objection to treat this step individually. At the end of this step, each decision-maker disposes on the evaluation table as displayed in Figure 3, completed with the preference functions and the weights that he has defined.

Step 9. The individual Promethee-Gaia analysis.

According to the PROMETHEE-GAIA methodology, the following quantities can now be computed for each DM_r:

$$\begin{cases} \pi^r(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j^r \\ \phi^{+r}(a) = \sum_{x \in A} \pi^r(a,x) \\ \phi^{-r}(a) = \sum_{x \in A} \pi^r(x,a) \\ \phi^r(a) = \phi^{+r}(a) - \phi^{-r}(a) \end{cases} \qquad [4.5]$$

For each a belonging to the set A of alternatives, $\phi^{+r}(a)$ and $\phi^{-r}(a)$ respectively measure the power and the weakness of a with regard to the other alternatives and $\phi^r(a)$ is a value function, such that the higher its value, the better a. $\phi^r(a)$ is called the *net flow* of alternative a for DM_r.

Each decision-maker has thus access to the three main PROMETHEE-GAIA tools:

- PROMETHEE I partial ranking,
- PROMETHEE II complete ranking,
- GAIA plane.

The PROMETHEE I partial ranking allows incomparabilities. This happens usually when one alternative is good on a subset of criteria on which another one is weak and vice versa. PROMETHEE II provides a complete ranking of the alternatives from the best to the worst ones and the GAIA plane displays graphically the relative position of the alternatives with regard to the criteria and the conflicts between the criteria. Additional tools, such as the walking weights and the decision stick, are also available to the decision-makers (cf. [BRA 94]).

Although the set of alternatives and the set of criteria are identical for all decision-makers, the evaluations can be quite different according to the individual weight distributions. It depends strongly on the actual feelings and specific interests of the decision-makers. Some decision-makers will for instance pay more attention (give more weight) to technological criteria, others to financial ones, and still others to socio-economical or environmental ones.

During the first stage, each decision-maker works individually, with the possible assistance of the facilitator. At the end of this stage, everybody has a good personal view of the decision problem. Everybody has ideas on how to decide. More precisely, the values of the $\phi^r(.)$ summarize the rankings of each decision-maker.

At the end of this step, the facilitator can display and comment one by one the results obtained by the different decision-makers. It is up to the second stage to provide a global evaluation and to analyze the conflicts.

5. Group evaluation stage

The purpose is now to focus on group decision support in order to take into account the specific points by view of the different decision-makers.

Step 10. Global evaluation matrix

At the end of the individual evaluation stage, the facilitator collects the data coming from the R decision-makers. More precisely, he obtains the following net flows:

$$\phi^r(a_i) \qquad i = 1,2,\ldots n,\ r = 1,2,\ldots R \qquad [5.1]$$

According to (3.5) it is easy to prove that

$$\phi^r(a_i) = \sum_{j=1}^{k} \phi_j^r(a_i) w_j, \qquad [5.2]$$

if

$$\phi_j^r(a_i) = \sum_{x \in A} \left\{ P_j(a,x) - P_j(x,a) \right\} \qquad [5.3]$$

where $\phi_j^r(a_i)$ is the single criterion net flow obtained by considering only criterion $f_j(.)$ for DM_r.

Let us suppose that there is an agreement on the weights fixing the relative power of each decision-maker in the group and let

$$\omega_1, \omega_2, \ldots \omega_r, \ldots \omega_R \qquad \left(\sum_{r=1}^{R} \omega_r = 1 \right) \qquad [5.4]$$

be these weights.

The net flow [5.2] is representative of the preferences of each decision-maker. The higher this net flow, the better the corresponding alternative for DM_r.

Moreover, this net flow directly defines the PROMETHEE II ranking for each DM_r. It can therefore be considered as a criterion summarizing the point of view of each decision-maker. A new matrix $(n \times R)$ is then obtained, including the n basic alternatives and R criteria that correspond with the R decision-makers as displayed in Figure 5.

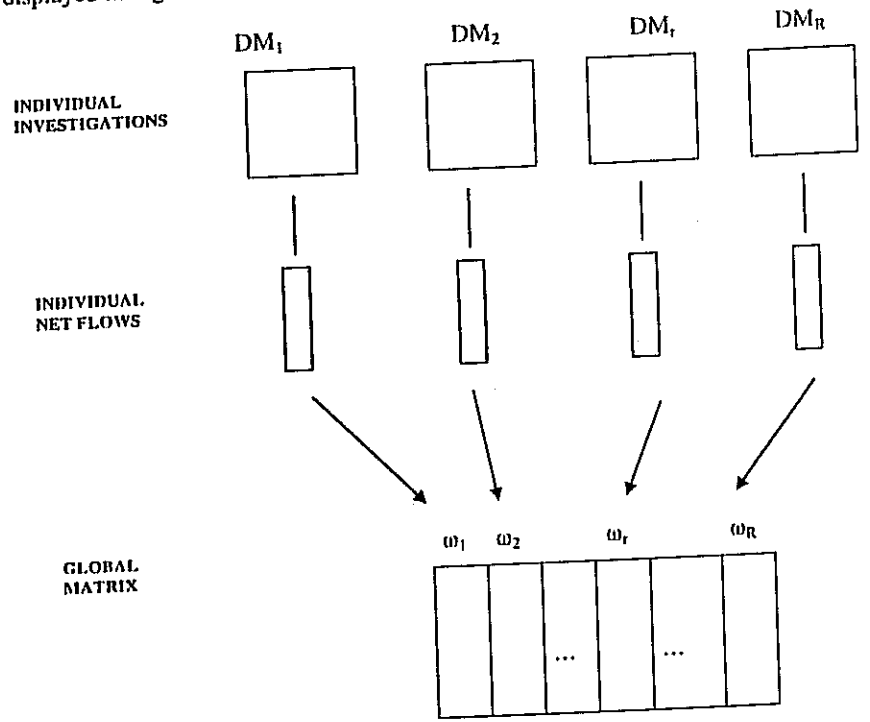


Figure 5. *From individual investigations to global evaluation matrix*

This is a rather small matrix, which can easily be analyzed by the PROMETHEE-GAIA methodology.

Step 11. Global evaluation.

In order to analyze the previously obtained matrix, a preference function should be assessed to each of these decision-makers criteria. However, it seems not realistic to assess different preference functions to these criteria, i.e. to each decision-maker. Their respective individual net flows are computed on the basis of individual preferences and are therefore expressed on the same preference scale. As all the criterion values are expressed in the same units, these values can directly be aggregated. Consequently, it seems quite natural to simply compute the weighted

sum of the individual net flows, so that the global net flow for the whole group, for a particular alternative, will be defined as:

$$\Phi^G(a_i) = \sum_{r=1}^{R} \phi^r(a_i)\omega_r \qquad [5.5]$$

This global net flow immediately provides the PROMETHEE II ranking of the alternatives according to the global preference of the group - see Figure 6. This special treatment, without preference function, as described above, is called the "0-option" in the PROMCALC-GAIA software. It allows of course to obtain not only the PROMETHEE II complete ranking, but also the PROMETHEE I partial one and the group GAIA plane as displayed in Figure 7.

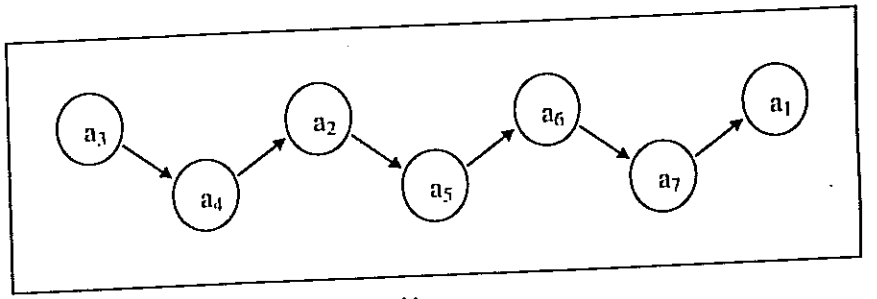


Figure 6. *Global PROMETHEE II ranking*

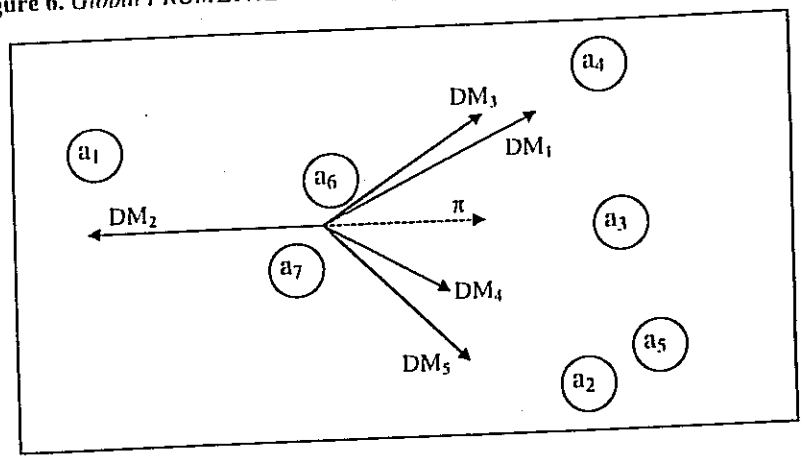


Figure 7. *Global GAIA plane*

The global GAIA plane and the global PROMETHEE II ranking can easily be interpreted. It appears clearly in Figure 7 that DM_1 and DM_3 have rather close

preferences, as well as DM_4 and DM_5, while DM_2 seems strongly in conflict with the other decision-makers. According to the global PROMETHEE decision axis π, the group is invited to decide in favor of a_3 and possibly a_2, a_4 and a_5. Alternative a_1 seems particularly attractive for DM_2 while a_6 and a_7 are rather neutral. The PROMETHEE II ranking confirms this.

6. Conflict resolution

At the end of Step 11, a global evaluation is obtained for the group. PROMETHEE II proposes a best compromise and the conflicts between the decision-makers are displayed in the GAIA plane.

If the group is agreeing upon the results of the global analysis, the best compromise can be adopted and the GDSS-PROMETHEE session can be closed.

On the other hand, if for some reasons some decision-makers don't agree on this compromise, the conflicts have to be faced. Of course, there is no general rule for the conflict resolution, it depends on the nature of each problem. The GDSS-PROMETHEE procedure remains, however, flexible and we can recommend some behaviors such as:

1. Cycle back to Step 11 and let the facilitator investigate other weight distributions for the decision-makers using the sensitivity analysis tools of the PROMCALC-GAIA software, such as the walking weights and the decision stick. In case of agreement, a new consensus could be reached.

2. Cycle back to Step 9 and let each decision-maker investigate other individual weights using the sensitivity analysis tools in order to obtain new individual rankings. New rankings mean new net flows and, consequently, a new global evaluation matrix and, finally, new compromises.

3. Cycle back to Step 6 and modify the set of the evaluation criteria by reconsidering criteria that are more sensitive to the conflicts.

4. Cycle back to Step 3 and modify the set of the alternatives, possibly by generating new ones, and more especially, whenever possible, by combining alternatives in order to reduce the conflicts.

5. Cycle back to Step 1 and include additional decision-makers. It is well known that in case of blocked economical negotiations between managers and trade unions, an additional government mediator can help the actors to find a compromise.

7. Alternative global evaluation approach

Let us suppose that the individual PROMETHEE evaluations of the first stage

The global evaluation has then to be performed: instead of considering the net flows obtained by each decision-maker and to merge them in a $(n \times R)$ evaluation matrix (cf. Figure 5), we can also bring all the criteria of each decision-maker together in a larger $(n \times k \cdot R)$ matrix as outlined in Figure 8.

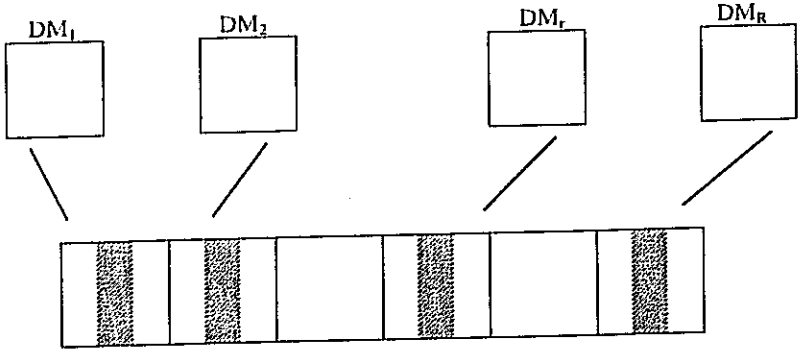


Figure 8. *From individual investigations to global evaluation*

We are then facing a global multicriteria problem including all the alternatives and all the criteria as considered by each decision-maker separately. In this case, a particular criterion appears R times in the table, possibly with weights equal to zero if some decision-makers consider this criterion as non relevant to their own analyses.

The PROMETHEE-GAIA methodology can, of course, be directly applied to this global problem. The preference functions have already been specified by the decision-makers during the first stage and the weight of each criterion is obtained by multiplying the individual criterion weight by the weight ω_r assigned to the corresponding decision-maker.

Consequently, the global PROMETHEE II net flow can be computed as usual. Taking into account [4.1], [5.3] and [5.4], we obtain for one particular alternative a_i:

$$\phi^G(a_i) = \sum_{r=1}^{R} \sum_{j=1}^{k} \phi_j{}^r(a_i) \cdot w_j \cdot \omega_r \qquad i = 1,2,\ldots n. \qquad [7.1]$$

The best compromise for the group is then the alternative having the highest net flow $\phi^G(.)$. In addition, the PROMETHEE I partial ranking, as well as the global GAIA plane, can be used for sensitivity analysis and decision aid. The advantage of

this approach is that all the information coming from the different decision-makers is explicitly taken into account. Nothing gets lost by preliminary aggregation.

Unfortunately, the size of the problem is obviously quite larger, which is of course a major disadvantage. It is not easy to get a clear view of the problem, especially in the GAIA plane, which now includes $k \cdot R$ criteria.

However, this approach can be useful, at least for the two following points:

1. First, it is easy to show that:

$$\Phi^G(a_i) = \phi^G(a_i) \qquad i = 1,2,,\ldots n \qquad [7.2]$$

holds.

Indeed, according to [5.5] we have

$$\Phi^G(a_i) = \sum_{r=1}^{R} \phi^r(a_i)\omega_r ,$$

where $\phi^r(a_i)$ is the individual net flow of DM_r as defined in [5.2].

Moreover, as:

$$\phi^r(a_i) = \sum_{j=1}^{k} \phi_j{}^r(a_i).w_j$$

we obtain:

$$\Phi^G(a_i) = \sum_{r=1}^{R}\sum_{j=1}^{k} \phi_j{}^r(a_i).w_j.\omega_r = \phi^G(a_i).$$

This result is obtained only if no preference function is assigned to the decision-makers in Step 11, i.e. if the "0-option" is considered. It is due to the additive aggregation character of the PROMETHEE methodology resulting from [4.5].

Consequently, the PROMETHEE II ranking obtained in Step 11 and the one obtained by the alternative global evaluation approach are identical. The approach of Step 11 seems, however, more attractive, because it provides a direct conflict analysis between the decision-makers in the GAIA plane, as shown in Figure 7.

2. The PROMCALC software allows to temporarily remove some criteria from the analysis. It is then possible to consider one particular criterion as it is viewed by the different decision-makers. A $(n \times R)$ matrix including R replications of the same criterion is obtained. It provides a conflict analysis between all the decision-makers on that particular criterion. All the criteria can be treated in such a way, one at time, and the associated GAIA planes can be displayed so that the group clearly sees on which criteria there is a consensus and on which the decision makers diverge. This aspect is discussed in [MAR 94].

8. Example

To illustrate the above concepts and steps, we will now consider a simplified example. Let us imagine that an additional electricity power plant has to be built somewhere in the European Union. The problem faced by the European Union is to identify the best possible location. Although this example is artificial, the European Union is facing similar problems in many areas. In the transportation sector, for example, they face the problem of choosing the best location for intermodal terminals (cf. EMOLITE, Evaluation Model for the Optimal Location of Intermodal Terminals in Europe, a project funded by the European Commission under the transport trd programme of the 4th framework programme [MOR 97]).

Preliminary stage

The countries, members of the Union, have first been invited to introduce several proposals. Six possible locations have been proposed:

a_1 : ITALY	a_4: SWEDEN
a_2: BELGIUM	a_5: AUSTRIA
a_3 : GERMANY	a_6: FRANCE

A comprehensive description of each proposal has been made available by the proponents. Four decision-makers have been appointed to take part in the selection process. Each of them represents a specific economic interest:

DM_1 : (EP) Energy production

DM_2 : (ENV) Environment

DM_3 : (FIN) Finance

DM_4 : (TU) Trade Unions

The decision-makers gather in a GDSS-PROMETHEE room in order to reach a final decision. A PROMETHEE-trained facilitator, familiar with the problem, has been appointed.

Steps 1 to 4: The facilitator displays the six possible locations and their descriptions. An 'open-discussion' phase takes place. Comments on each site are made.

Step 5: The decision-makers are invited to enter their comments using their computers. Finally, the description/comments forms are obtained for each site, as for example for Italy and France (Figures 9 and 10).

Italy	
Description	**Comments**
Type : Solar power plant Location : Alps, North of Italy Power generated : 500 MW Manpower : 80 engineers Construction cost : 1000 MECU	Discontinuous production Touristic area 8 villages to evacuate

Figure 9. *Description/comments for Italy*

France	
Description	**Comments**
Type : Nuclear power plant Location : Rhone valley Power generated : 960 MW Manpower : 94 engineers Construction cost : 950 MECU	Nuclear risk Industrial area Already three plants in area

Figure 10. *Description/comments for France*

Step 6: An 'open-discussion' phase takes place on the evaluation criteria. The 11 following criteria are progressively formulated:

C_1	MP	Manpower (number of engineers)
C_2	POW	Power in MW
C_3	CC	Construction Cost
C_4	MT	Annual Maintenance Cost
C_5	VIL	Villages to evacuate
C_6	DAN	Danger for environment
C_7	SEC	Security level
C_8	CO	CO emission
C_9	SOC	Social impacts
C_{10}	TPT	Transport facilities to the plant
C_{11}	FIN	Financial Return

A consensus is reached on objective data for these criteria and the following evaluation table is obtained. In this case all the decision-makers agree on these objective data. This is not compulsory; each decision-maker may possibly have his own evaluations.

	C_1 MP	C_2 POW	C_3 CC	C_4 MT	C_5 VIL	C_6 DAN	C_7 SEC	C_8 CO	C_9 SOC	C_{10} TPT	C_{11} FIN
Italy	80	500	1000	5,2	8	0,5	9	0	2	300	4200
Belgium	55	580	250	3	1	4	3	5	8	175	900
Germany	83	600	450	3,8	4	3,5	7	65	6	125	850
Sweden	40	450	1000	7,5	7	0	10	0	10	450	900
Austria	52	880	900	3	3	4,5	2	10	5	150	750
France	94	960	950	3,6	5	3,5	4	10	3	250	2000

Figure 11. *Evaluation table*

First stage: indivinal evaluation

Step 7: The decision-makers are invited to assign individual weights expressing the relative importance of each criterion. Each decision-maker is not necessarily interested in the 11 criteria. A weight equal to zero will be assigned to the criteria considered as non-relevant. In addition, each decision-maker has the freedom to maximize or to minimize each criterion.

The individual choices are the following:

	C_1 MP	C_2 POW	C_3 CC	C_4 MT	C_5 VIL	C_6 DAN	C_7 SEC	C_8 CO	C_9 SOC	C_{10} TPT	C_{11} FIN
DM_1: EP	MIN 1	MAX 2	MIN 1	MIN 1	MIN 1	0	MAX 1	0	0	0	0
DM_2: ENV	0	0	0	0	MIN 1	MIN 1	MAX 1	MIN 1	0	0	0
DM_3: FIN	MIN 1	0	MIN 1	MIN 1	0	0	0	0	0	0	MAX 3
DM_4: TU	MAX 1	0	0	0	0	0	MAX 1	0	MAX 1	MIN 1	0

Figure 12. *Min/Max Options and weights*

The weights given here are not normed (this is accomplished automatically by the software). It is obvious that each decision-maker is not interested in all the criteria. We notice that the selected criteria are completely in agreement with the concerns of the decision-makers. We also notice that DM_1 (EP) wants to minimize manpower (MP) in order to reduce the costs, while DM_4 (TU) wants to maximize it for creating as much jobs as possible. This represents of course an extreme situation, but it illustrates how opposite points of view can generate strong conflicts between the decision-makers.

Step 8: According to the PROMETHEE methodology (cf. [BRA 85]) preference functions have to be assigned to the criteria. The facilitator plays here a major role to help the decision-makers. Finally the following choices have been made.

Criterion	name	Type	p, q, s –values
C_1	MP	2	q=10 for DM_1 and DM_3
C_1	MP	3	p=10 for DM_4
C_2	POW	3	p=300
C_3	CC	5	q=50, p=500
C_4	MT	4	q=1, p=6
C_5	VIL	1	-
C_6	DAN	3	p=5
C_7	SEC	6	s=5
C_8	CO	3	p=5
C_9	SOC	2	q=2
C_{10}	TPT	3	p=100
C_{11}	FIN	1	-

Figure 13. *Preference functions for each criterion*

Step 9: According to the additional information collected as mentioned above, each decision-maker now has the opportunity to complete his own individual PROMETHEE-GAIA analysis. The PROMETHEE II rankings obtained by each decision-maker are given in Figure 14. The individual GAIA planes can also be analyzed. All these individual results will be displayed and commented by the facilitator to the group.

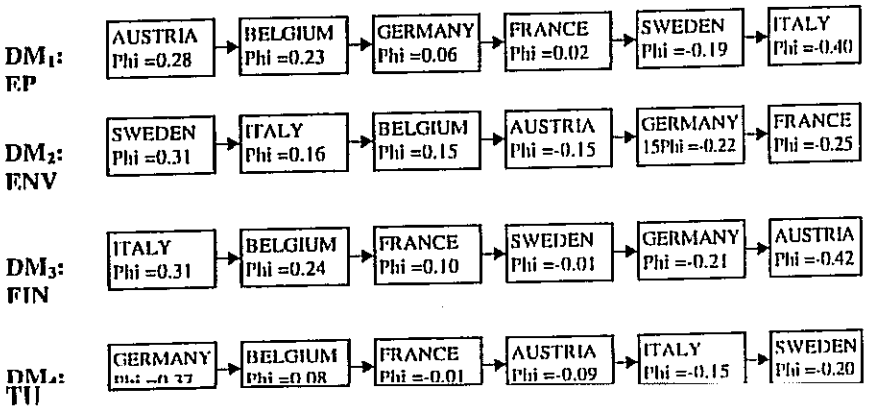


Figure 14. *PROMETHEE II rankings of each decisionmaker*

The best choice is obviously not the same for each decision-maker. DM_1(EP): AUSTRIA, DM_2(ENV): SWEDEN, DM_3(FIN): ITALY, DM_4(TU): GERMANY.

Second stage: global evaluation

Step 10: The PROMETHEE II net flows obtained by each decision-maker can now be collected by the facilitator who brings them together in the global evaluation matrix as displayed in Figure 15. Each column is representative of the decision-maker's point a view.

	DM_1 : EP	DM_2 : ENV	DM_3: FIN	DM_4: TU
ITALY	-0.40	0.21	0.28	-0.16
BELGIUM	0.23	0.10	0.28	0.09
GERMANY	0.06	-0.19	-0.25	0.38
SWEDEN	-0.19	0.37	-0.05	-0.20
AUSTRIA	0.28	-0.21	-0.42	-0.11
FRANCE	0.02	-0.29	0.17	-0.01

Figure 15. *Global evaluation table*

Step 11: The global PROMETHEE-GAIA analysis can now take place. According to the "0-option", no preference function is assigned to the decision maker's criteria and the weighted sum of the net flows is computed. In this case, all the decision-makers are supposed to have equal weights.

The PROMETHEE II ranking is then obtained. Although BELGIUM is never the best choice for any of the decision-makers separately, it appears as the best choice for the group. See Figure 16.

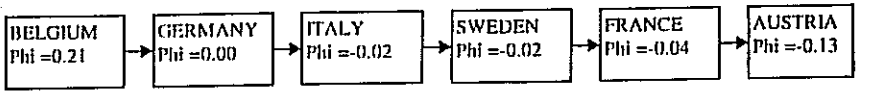


Figure 16. *Global PROMETHEE II ranking*

The global GAIA plane confirms this impression (Figure 17). The PROMETHEE decision axis π is clearly oriented towards BELGIUM (A_2). On the other hand, the conflicts between the decision-makers are very well displayed. DM_1 (EP) and DM_4 (TU) are strongly in conflict with DM_2 (ENV). For these decision-makers, BELGIUM seems to be a good compromise, while BELGIUM seems a rather good choice for DM_3(FIN).

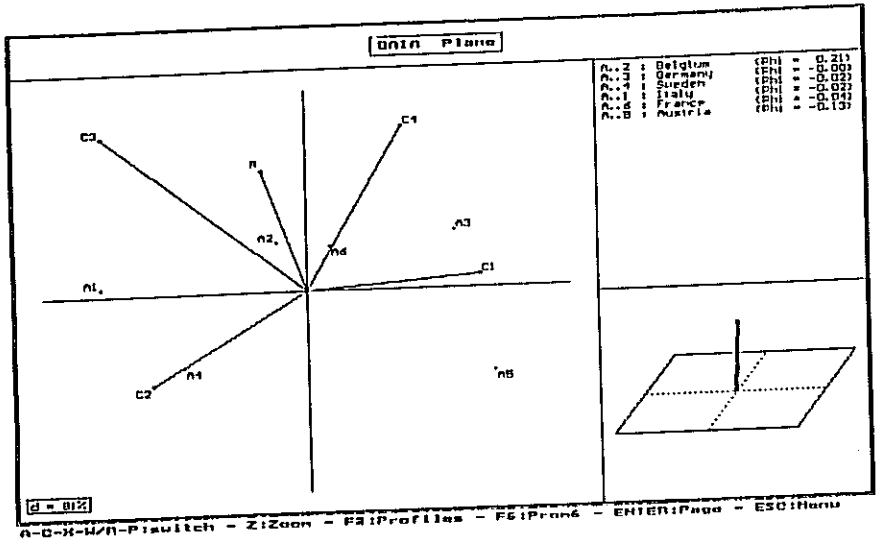
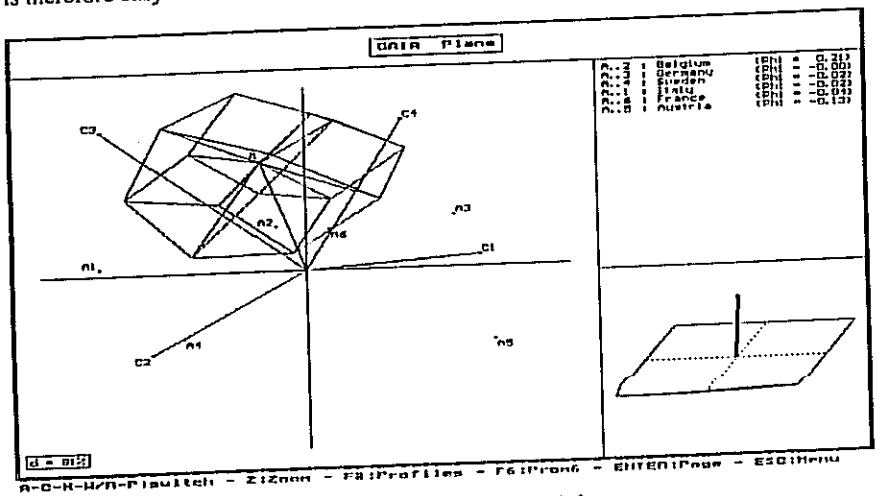


Figure 17. *Global GAIA plane*

In addition, a PROMETHEE VI sensitivity analysis reveals that the consensus that has been reached is rather robust with respect to the weights assigned to the decision-makers. The polygon in Figure 18 shows the location of the tip of the decision axis when the weights are modified within a +/- 50% interval. As shown, even with such a 50% margin on the weights, the PROMETHEE decision axis π still remains oriented towards BELGIUM. The selection of BELGIUM thus seems to be quite robust with respect to the weights of the decision-makers and the problem of reaching a consensus is therefore easy to solve in this particular application [BRA 95b].



As a further development of this selection problem, one could imagine that the E.U. considers building not only one, but several power plants. In this case, the problem is not to select one best compromise, but a best subset of alternatives. In such a case, additional constraints should usually be taken into account, such as the total manpower engaged, or the total energy requirements, or various clustering constraints... The PROMETHEE V module available on the PROMCALC software can be used for this purpose (cf. [BRA 92]). Suppose for instance that the E.U. wants to create at least 150 jobs and to produce in addition at least 2000 MW more in three power plants. These constraints are translated in a (0-1) linear program taking into account the global PROMETHEE II ranking obtained at the end of the second stage. The best subset is then obtained as follows:

(BELGIUM, GERMANY, FRANCE).

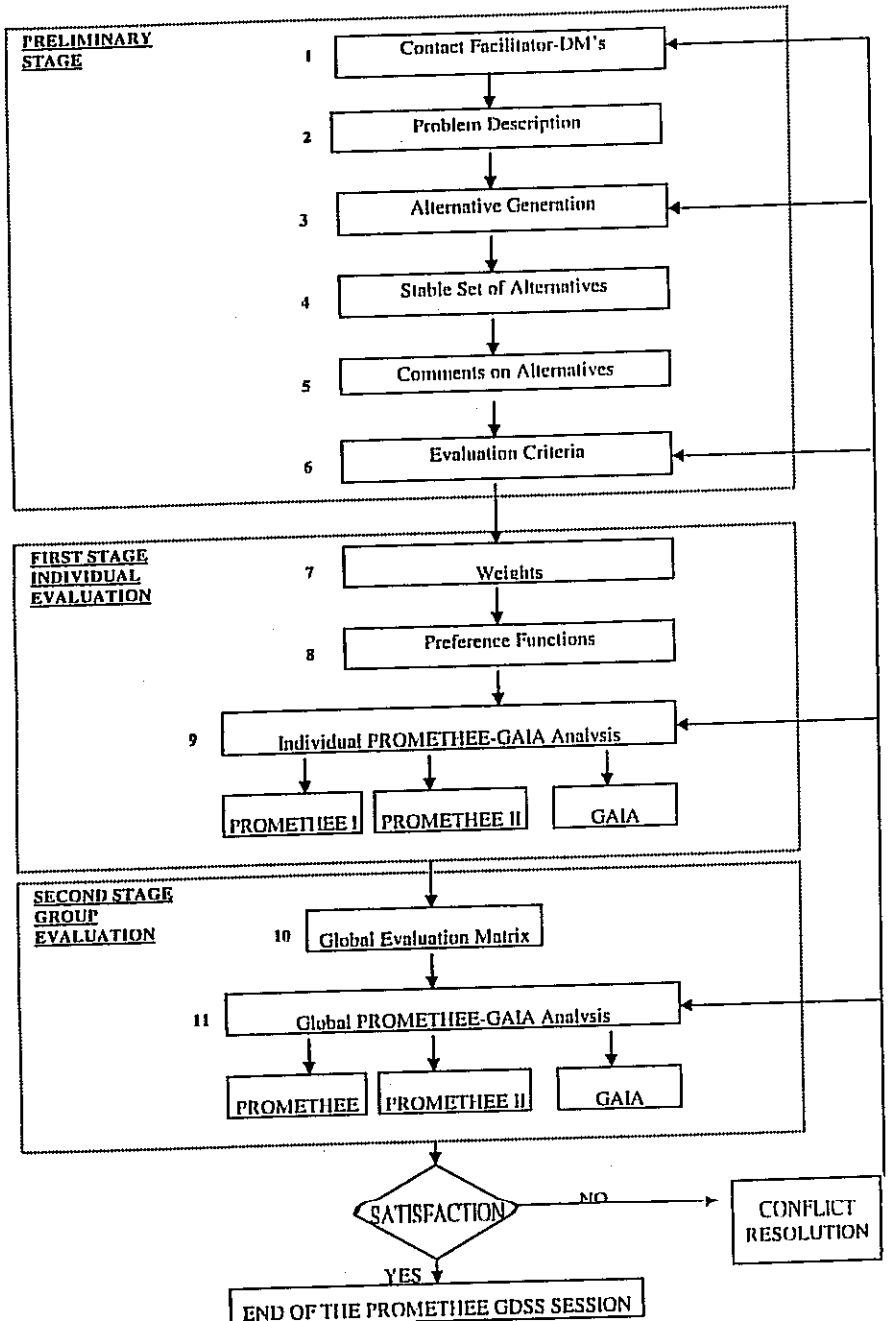
9. Conclusions

The GDSS PROMETHEE procedure is a powerful multicriteria tool to help a group of decision-makers to achieve a consensus.

The preliminary stage is particularly useful to generate alternatives and criteria. 'Open- discussion' phases alternate with 'computer' phases so that no ideas get lost. The individual evaluation stage enables each decision-maker to investigate his own objectives and to get a better understanding of the problem. The global evaluation stage allows to obtain a 'best consensus' solution for the group and to display the possible conflicts between the decision-makers. Some feedback, depending on the complexity of the problem, is suggested in order to solve the conflicts. Also the sensitivity analysis tools of PROMETHEE and GAIA are particularly useful: weight distribution of the decision-makers, weight distribution of the criteria, decision stick, additional alternatives, additional criteria, additional decision-makers.

The role of the facilitator in a GDSS-PROMETHEE room is crucial. On one hand, the facilitator must be familiar with the PROMETHEE methodology, and on the other hand, he needs a good knowledge of the problem. The length of a GDSS-PROMETHEE session is extremely variable. It will take at least half a day, and up to one or two weeks, depending on the importance and the complexity of the problem. The more the facilitator has prepared the session, the easier and the more efficient it will be.

The GDSS-PROMETHEE software is a client/server system implemented in JAVA for the use on Internet or on an Intranet network. Each participant is able, through his personal workstation, to interact with the facilitator and the other participants. The system is developed jointly by the VUB/ULB universities and by EDS (Electronic Data System) in Brussels. It can be implemented anywhere. Moreover, it is foreseen to install a GDSS-PROMETHEE room at the VUB for further research and for practical applications.



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