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PROMETHEE-GDSS Revisited: Applications So Far and New Developments

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PROMETHEE-GDSS Revisited: Applications So Far and New Developments

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Abstract: The PROMETHEE method, developed by Brans and Mareschal (Brans, 1982; Brans and Mareschal, 1994) has been extended to be used in the group decision context (as described in Macharis, Brans and Mareschal, 1998). PROMETHEE has thus been embedded in GDSS and has been widely used in various decision contexts. The aim of the paper is to analyze how PROMETHEE-GDSS has been applied and which further developments can enhance its applicability. The analysis is structured along a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) and on the basis of this analysis recommendations are given.

Key Words: GDSS, GMCDA, PROMETHEE, Stakeholders.

1 Introduction

Group decision support systems (GDSS) are a class of electronic meeting systems, a collaboration technology designed to support meetings and group work (Dennis et al., 1988). Within the last two decades several multicriteria analysis methods were adapted to be used in a group decision context (for an overview see Álvarez-Carrillo et al., 2010). They are called Group Multicriteria Decision Support System (GMCDSS) or Multicriteria Decision Support System (MCDSS). According to Banville et al. (1998), the groups of methods can be classified according to the moment the preferences of the stakeholders are introduced. This can be done *a priori* by using an aggregation procedure in which all potential actions are compared through their respective performance. This kind of aggregation can range from a single synthesis criterion approach, as used in the Multi Attribute Utility Theory (MAUT) and the Analytical Hierarchy Process (AHP) approach or a synthesis outranking approach as used in ELECTRE and PROMETHEE. It can also be done *a posteriori* by an efficient set determination method or *progressively* with interactive methods. The latter two approaches were developed largely within the framework of multi objective programming.

In most of these approaches a common hierarchy (or in other words a criteria set) for all the stakeholders is considered. The group is assumed to be homogeneous, which is a normal assumption for group decisions in an organizational context. Even if different departments have opposite views (marketing, operations, ...), at the end of the day they have an overall goal; i.e., to create more value for the firm. So, even if there are opposite kind of views they can use the same hierarchy tree to start from. However, in social decision problem contexts it is clear that the group will not be homogeneous and have different and often conflicting points of view. Social multicriteria analysis (SMCA), as defined by Munda (2004), looks at decision problems within the society as a whole and puts itself in the domain of public choice. In this context, problems are multidimensional and the evaluation of public plans or projects has to be based on procedures that explicitly require the integration of a broad set of various and conflicting points of view (Munda, 2004). A common value tree/hierarchy/criteria set is in such a context not always possible. Stakeholders could share a common global list of issues and criteria, even they could belong more or less to a subset of them, but still disagreeing about the relative importance those criteria play in the problem setting. They could also disagree both on the issues and criteria, and on criteria relative importance.

So the difference between the GMCDSS methods is mainly based on the extent to which the information is brought together. One could talk about input level aggregation or output level aggregation as Leyva-Lopez (2010) do. Or one can also make a difference between models with a same value tree for all stakeholders or with different value trees for each stakeholder (De Brucker et al., 2011). The same value tree corresponds mainly to input level aggregation where the group is asked to agree on a common set of criteria, weights and remaining parameters. This context necessitates a strong input from decision aiding people, focussing mainly on consensus and underestimating conflicting points which could reappear later in the decision process like for example during implementation. If several individual value trees exist and are only aggregated at the end, we talk about 'output level aggregation'. In the evaluation of transport projects it is important to distinguish different points of view, hence different value trees and output level aggregation is most appropriate. The Multi Actor Multi Criteria Analysis developed by Macharis et al. (2009) allows working with different value trees per stakeholder group. A classification within the GMCDSS can be represented as follows (Figure 1).

	One value tree	For each actor a value tree
Business	Most of the applications and methods	
Social	SMCA	MAMCA

Figure 1: Classification of multi criteria group decision making (Source: Macharis et al., 2012)

This paper focuses on the PROMETHEE-GDSS method which belongs to the outranking methods. The PROMETHEE method has been developed since 1982 by Brans and Mareschal (Brans, 1982; Brans and Mareschal, 1994). In Macharis, Brans and Mareschal (1998) the PROMETHEE-GDSS method was developed.

It was shown that the PROMETHEE net flow can be used to represent the arguments of the different actors involved in the decision making process and that this can also be displayed in the GAIA plane (see Section 2). Initially, it was developed to be used in organizational setting, but later on also social applications were executed (Côté et al., 2001; Wotto and Waaub, 2003 and 2006). The method allows using different value trees within one larger model and as a consequence, it can be used in the MAMCA methodology. PROMETHEE has thus been embedded in GDSS and has been widely used in various decision contexts.

The aim of the paper is to analyze how PROMETHEE-GDSS has been applied and which further developments can enhance its applicability. First, an overview of the stakeholder importance is discussed in the framework of a generic GMCDSS process (Section 2). Secondly, the presentation of the PROMETHEE-GDSS method (Section 3) is given. Then, a literature review of different applications is presented (Section 4). The analysis of those case studies is structured along a SWOT analysis (Strengths, weaknesses, opportunities and threats) in Section 5 and on the basis of this analysis recommendations are given (Section 6).

2 The importance of stakeholders in GDSS-MCDA process

A generic GMCDSS process involves 9 steps not necessarily in a linear path: (1) problem setting and stakeholder mapping; (2) alternative listing; (3) translating concerns and issues into criteria; (4) choosing measurement indicators and scales; (5) weighting criteria according value systems; (6) evaluating all alternatives against all criteria; (7) choosing and implementing an aggregation procedure (in our cases PROMETHEE); (8) deliberating, negotiating and recommending solutions; (9) decision.

Within the context of GMCDSS, it is very important to remind that the decision process is a scene involving many actors about complex societal problems. The promoter is the one that initiates an action (a project or a strategic proposal and alternatives). Often, assessment of the options is made under a regulatory institution or organization which can be called an authority in charge or responsible for managing the decision process and thus allowing financial and human resources into a timeframe. The group of people which participate in the decision process can be composed by stakeholder representatives from civil society, institutions or ministries, economic sector and organized expertise (Prades, Loulou and Waaub, 1998; Côté et al., 2001). The decision process can also benefit from supporting experts in different fields as participatory processes, decision aiding, communication, and diverse sectorial issues (Côté and Waaub, 2012). At the end, even the decision process encompasses many intermediate decisions; one or more decision makers will make the final decision by authorizing the implementation by the promoter of the chosen alternative. Each actor has a specific role and responsibilities throughout the process. We can have a better understanding of these roles by focusing on the concept of stakeholders.

The concept of stakeholders was introduced in the research field of strategic management (Williamson, 1991). These stakeholders needed to be taken into account due to the fact that firms were increasingly focusing on corporate social responsibility (Donaldson and Preston, 1995; Buysse and Verbeke, 2003). Freeman (1984) defines a stakeholder as 'an individual or a group of individuals who can influence the objectives of an organization or can be influenced themselves by these objectives'. So this definition is very organizational/business oriented. For Banville et al. (1998) who makes a very convincingly plea for the inclusion of stakeholders within MCDA, a stakeholder is everyone who has a vested interest in a problem in any of the three following ways: 1° by mainly affecting it, 2° by mainly be affected by it and 3° by both affecting it and being affecting by it. It seems that the stakeholder perspective of Banville is also inspired by an organizational setting, when he mentions among other things, that the choice of stakeholders depends on his/her role in the decision making process, i.e. those stakeholders whose potential for cooperation is low, will be less likely retained for participation. Within a social context, this kind of approach would be quite unethical, as all relevant points of view should be incorporated. Also, Munda (2004) reacts on this definition as it only recognizes relevant organized groups, while he prefers to talk about social actors. This term is broader in the sense that it covers a societal perspective and not a business perspective and in addition incorporates also non-organized groups. Indeed, in societal contexts often the point of view of unorganized groups should be incorporated, such as the vision of future generations, groups that are unable to organize themselves or sit together around the discussion table. In the definition of Grimble and Wellard (1997), this is in our opinion

well incorporated: "Stakeholders are any group of people, organized or not organized, who share a common interest or stake in a particular issue or system". A stakeholder should be rather defined based on his/her stake in the issue as this determines whether he/she can affect or will be affected by the ultimate outcome. Grimble and Wellard (1997) call the ones who affect, the active stakeholders, and those who are affected, the passive ones. Another useful distinction can be made according to the relative influence (the power certain stakeholders have over the success of a project) and importance of the stakeholders (those whose needs and interests are the priorities of aid) (Grimble and Wellard, 1997). At the strategic level, it is not manageable to involve directly individuals from the general public. Stakeholders should then be representatives of organized or non-organized groups.

So although the notion of stakeholders is always somewhere there within GMCDSS, it is not always well used in practice.

3 PROMETHEE-GDSS

The PROMETHEE method can be used to analyze multicriteria problems including a finite set of n alternatives and k criteria. The basic data are an evaluation table where the alternatives are evaluated on the different criteria. Quantitative as well as qualitative criteria can be considered. Besides this, additional information is required to model the preferences of the decision-maker.

First, for each criterion $f_j (j = 1, \ldots, k)$ a specific preference function $P_j(a, b)$ has to be defined to translate the deviation between the evaluations of any two alternatives a and b into a preference degree ranging from 0 to 1. This preference function is a non-decreasing function of the deviation $d = f_j(a) - f_j(b)$ between the evaluations of the alternatives on the considered criterion , as shown in formula 1. A preference function is associated with each criterion, whether qualitative or quantitative.

$$P_j(a, b) = G_j \{f_j(a) - f_j(b)\} \tag{1}$$

In order to facilitate the selection of a specific preference function, six possible shapes of preference functions are proposed to the decision-maker by Brans et al. (1986) (usual shape, U-shape function, V-shape function, level function, linear function and Gaussian function). In practice they are sufficient to address most cases but some types are more used than others. Thus the usual preference function is a good choice for qualitative criteria including a small number of evaluation levels (like the often used 5-point scale ranging from very bad to very good). The level preference function is a good choice for qualitative criteria with a larger number of levels. The linear preference function, (and U-shape, V-shape, as a special case) is the best choice for most quantitative criteria (Brans and Mareschal, 2005; Podvezko and Podviezko, 2010).

Second, information on the relative importance of the criteria (weights) is required. PROMETHEE assumes that the decision-maker is able to weigh the criteria appropriately, at least when the number of criteria is not too large. For larger numbers of criteria, weights can be determined according to several methods: direct rating, point allocation, trade-off, pairwise comparisons via the AHP method, among others (Macharis et al., 2004). This information is used to compute an multicriteria preference index $\pi(a, b)$ taking into account all the criteria (see formula 2). The values themselves can be quantitative or qualitative.

The multicriteria preference index is the basis for the computation of the positive $\varphi + (a)$ and negative $\varphi - (a)$ preference flows that measure, on average, how each alternative (a) is outranking (see formula 3) or is outranked (see formula 4) by the other $n - 1$ alternatives. The difference between these two preference flows is the net preference flow $\varphi(a)$ (see formula 5), which is a value function whereby a higher value reflects a higher attractiveness of alternative a.

$$\begin{cases} \pi(a,b) = \sum_{j=1}^{k} w_j P_j(a,b) & (2) \\ \varphi^+(a) = \frac{1}{n-1} \sum_b \pi(a,b) & (3) \\ \varphi^-(a) = \frac{1}{n-1} \sum_b \pi(b,a) & (4) \\ \varphi(a) = \varphi^+(a) - \varphi^-(a) & (5) \end{cases}$$

Several PROMETHEE procedures can be used to analyze the multicriteria decision problem. Among them the most often used are the PROMETHEE I partial ranking, the PROMETHEE II complete ranking and the GAIA plane. In PROMETHEE I, a partial ranking is obtained from the positive and negative preference flows (see formulas 3 and 4). Given two alternatives a and b, a is preferred to b if the positive flow of a is no lower than the positive flow of b, the negative flow of a is no greater than the negative flow of b and at least one of the two inequalities is strict. As a result, PROMETHEE I allows incomparability between alternatives. PROMETHEE II produces a complete ranking of all the alternatives from the best to the worst one, based on the net preference flow (see formula 5). The GAIA (Geometrical Analysis for Interactive Aid) plane is a visual representation of the decision problem in which the alternatives and their contribution to the criteria are displayed. Additionally, a decision stick can be used to further investigate the sensitivity of the results as a function of weight changes (Brans and Mareschal, 1994).

In the context of group decision, the PROMETHEE method has been extended to PROMETHEE-GDSS (Macharis et al., 1998): we suppose that R stakeholders ($ST_r, r = 1, \ldots, R$) are evaluating the same set of alternatives using PROMETHEE. As each stakeholder has specific preferences a different net flow is obtained for each of them:

$$\phi^r(a_i) \qquad i = 1, 2, \ldots, n, \quad r = 1, 2, \ldots, R \tag{6}$$

According to (2)–(5) it is easy to show that:

$$\phi^r(a_i) = \sum_{j=1}^{k} \phi_j^r(a_i)\, w_j \tag{7}$$

with

$$\phi_j^r(a_i) = \frac{1}{n-1} \sum_{x \in A} \left\{ P_j^r(a,x) - P_j^r(x,a) \right\} \tag{8}$$

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

Different weights (ω_r) can be assigned to the stakeholders when appropriate, otherwise equal weights are used:

$$\omega_1, \omega_2, \ldots \omega_r, \ldots \omega_R \qquad \left(\sum_{r=1}^{R} \omega_r = 1 \right) \tag{9}$$

The net flows (7) are representative of the preferences of each stakeholder. The higher the net flow, the better the corresponding alternative for ST_r. Moreover these net flows directly define the PROMETHEE II ranking for each ST_r. We therefore consider them as criteria summarizing the point of view of each stakeholder (Macharis et al., 1998). They form a new evaluation table that can be analyzed by PROMETHEE. For this purpose a special "0-option" preference function is used to simply calculate the weighted sum of the individual net flows (10). Indeed no preference function is required at this level as individual preferences have been taken into account for each stakeholder.

$$\Phi^G(a_i) = \sum_{r=1}^{R} \phi^r(a_i)\, \omega_r \tag{10}$$

This global net flow provides the PROMETHEE II ranking of the alternatives according to the global preference of the group. A GAIA-plane analysis can also be performed. It is based on a principal component analysis that allows defining a series of orthogonal dimensions (principal components) that keep as much information as possible after projection on the relative positions of the actions in the k-dimensional space. In the GAIA method the two first principal components are computed and displayed in the GAIA plane. This method gives the best possible two-dimensional representation of all data in a problem. As it contains a projection on a 2 dimensional plane, it however means that some information might get lost, especially when the decision stick is short. The amount of accuracy of the GAIA plane (the quantity of information retained) is denoted by a delta; the higher delta, the more information preserved (Brans and Mareschal, 2005) The axes then represent the points of view of the stakeholders and show the amount of consensus or conflict within the group (see Figure 2). Actions lying in the direction of an axis are scoring good on the criteria of that stakeholder. As instance for ST_1 and ST_3, the direction of the decision axis is towards a4 that is the best action for these stakeholders whilst a_7 with opposite direction to the decision axis appears the worst action (Figure 2).

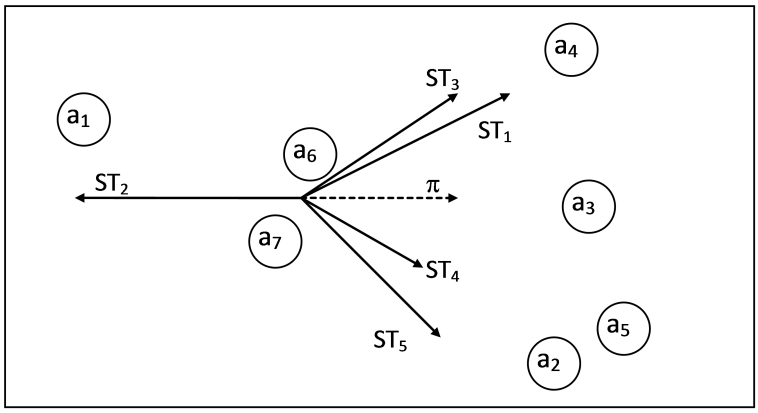

Figure 2: Global GAIA plane

The PROMETHEE VI procedure makes it possible to perform a sensitivity analysis showing the level of conflict between the stakeholders. In Figure 3, the polygon shows the location of the tip of the decision axis when the weights are modified within a +/− 50% interval. In Figure 3 it seems that a consensus can easily be reached as the polygon lies on one side of the GAIA plane.

Different software have been developed for the PROMETHEE method: PROMCALC, Decision Lab, D-Sight and the new Visual PROMETHEE software available for download on www.promethee-gaia.net.

4 Overview of applications

Recently, an extensive literature review on PROMETHEE methodologies and applications has been performed by Behzadian et al. (2010). It showed that PROMETHEE is increasingly used in a variety of domains such as environmental and natural resources management, logistics and transportation, energy planning, and so on.

Specific within PROMETHEE-GDSS we found the following chronological applications (Table 1).

The first application for which the PROMETHEE-GDSS method is incorporated in the MAMCA methodology is the choice of location for intermodal terminals. The so called LAMBIT-model (Location Analysis Model for Belgian Intermodal Terminals) provided the framework for the decision-making process on the location of new intermodal terminals (Macharis, 2000; Macharis, 2004). Interesting in this application is the combination with other socio-economic evaluation tools such as the cost-benefit analysis as one of the criteria.

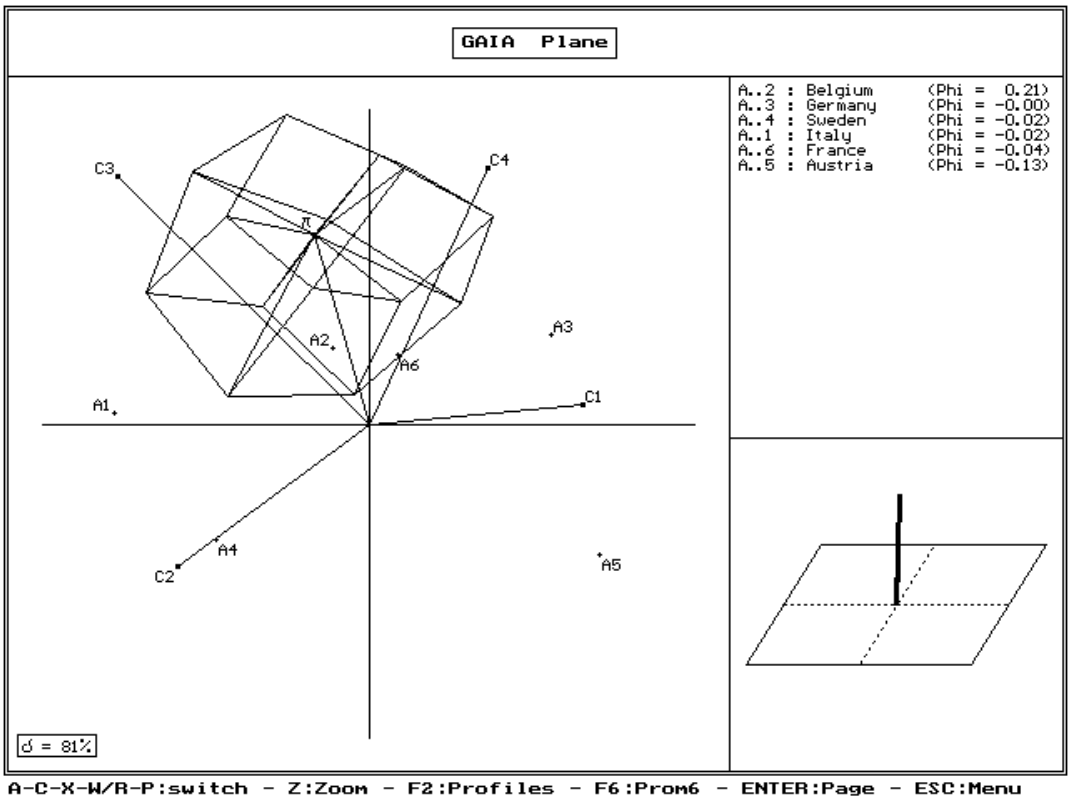

Figure 3: PROMETHEE VI with 50% margin on the weights (Source: Macharis et al., 1998)

Martin et al. (2000) presented the result of a pilot project conducted in a watershed management context in the Quebec City metropolitan area. A round table of stakeholders was at the core of the project. This took about 6 months, which illustrates that the PROMETHEE-GDSS approach might need time for iterative work and discussion. The role of a supporting team and the need to integrate capacity building taking into account both the process and the tools were emphasized.

In Côté et al. (2001) the PROMETHEE-GDSS method is integrated in a larger integrated decision support system with GIS related tools. A multilevel GIS was designed, including ecological mapping for land use planning and socioeconomic databases. The idea was also to benefit from a more powerful decision aid tool than the classical weighted average sum embedded in most of GIS software and overlay approaches. A regional agency called LATINO (an agency coordinating the numerical information related to the full administrative Outaouais region in the Quebec Province which is about 35 000 km^2). Illustrative examples were simulated, dealing with locating waste management facilities and with consolidating regional biodiversity planning.

The paper of Harahambopoulos and Polatidis (2003) concluded that participation and discussion among the stakeholders is crucial to achieve good results. In their application still a lot was done via computer interaction and not real live interaction which did not allow using all sensitivity tools that could help to come to a consensus.

A few applications conducted at GEIGER (Interdisciplinary Research Group in Geography and Regional Environment) under the supervision of Waaub are focusing on tiering PROMETHEE-GDSS approach to the decision process related to strategic environmental assessment (SEA) in different contexts. Among those projects, Waaub et al. (2005a; 2005b) reported challenges and results from adaptation to First Nation pilot project related to an endogenous territorial planning process facing the Quebec forest management planning process in a context of ongoing territorial Nation to Nation negotiation. This changes a lot the way stakeholders are involved. Instead of being involved through diverse sectorial consultation processes, an

Table 1: PROMETHEE-GDSS applications

Publication	Subject	Actors
Macharis (2000; 2004)	Location of intermodal terminals	The users of the terminal, the operators/investors and the community as a whole
Martin, St-Onge, Waaub (2000)	Watershed management, Quebec city metropolitan area	Round table with stakeholders such as planning authorities, environmental and riverside residents NGOs
Côté et al. (2001)	Land use planning, biodiversity management, waste management siting for Outaouais administrative region in Quebec province	Land use planners, promoters, civil servant from relevant ministries belonging to a regional association for managing territorial electronic information
Harahambopoulos and Polatidis (2003)	Renewable energy projects	Local authorities, potential investors, central government and public pressure groups
Waaub et al. (2005a; 2005b)	Strategic environmental assessment of First Nation forest management scenarios, Quebec, Canada	Territorial representatives, fauna and forest management representatives, elders, civil servants from Nation Council
Kourouma (2005) and Kourouma, Waaub (2004)	Strategic environmental assessment of energy system in Maritimes Guinea	Civil servants from involved ministries, NGO's representatives
Wotto, Waaub (2003; 2006)	Strategic environmental assessment of transportation planning scenario in metropolitan Montreal	25 representatives from various sectors involved in transportation planning
Vaillancourt, Waaub (2006)	GHG emission permit allocation at world level	Simulation of group of countries
Samoura, Bouvier, Waaub (2007)	Planning Mangrove Ecosystems in Guinea	People from mangrove communities, representatives from ministries
Morais and Teixeira de Almeida (2007)	Leakage management strategies of a water network of a city	The water company representative, the consultant-engineer, the environmental agency and a community representative
Samoura (2010)	Strategic environmental assessment of hydroelectric dams development in Guinea	Civil servants from involved ministries, NGO's representatives
Alancar and Teixaira de Almeida (2010)	Project team for a civil construction project	Technical engineer, a quality engineer, a security and environment engineer, a budget manager and a contract manager
Behzadian et al. (2011)	House of Quality in a new generation automotive part for a supplier	Research and design director, three master designers
Turcksin et al. (2011)	Selection of the most appropriate package to stimulate a clean vehicle fleet	Car manufacturing industry, user organizations, policy makers

endogenous SEA process was adapted and designed to fit First Nation values and processes (ex.: schedule of meetings, way of conducting discussions, problem setting, use of traditional knowledge etc.).

Some applications were also about African cases, such as Kourouma and Waaub (2004) and Kourouma (2005) in energy planning in Guinea. The stakeholders involved are mainly from different ministries having competencies on the subject and also national NGOs. Considering the political and institutional context the use of a formal decision support tool is a significant improvement in the planning process. Most of the work about implementing the PROMETHEE-GDSS is done by a supporting team. There was no direct use of software during the meetings. Information and documentation about each step was prepared to be discussed by the stakeholders. A "translation" and adaptation was needed to face the specific needs of civil servants representative of their ministries. This problem was even important in Samoura et al. (2007)

who used the PROMETHEE-GDSS to perform a Strategic Environmental Assessment (SEA) for Planning Mangrove Ecosystems in Guinea which involved people having very contrasted level of knowledge, some of them were even analphabetic. They concluded that participation is essential and that the approach followed was interesting to be used in Africa. The approach was then used at the river basin management level in a 5 year projects (Samoura, 2010) dealing with SEA of cumulative hydroelectric development plan alternatives. This application was combining GIS, hydrology modelling and PROMETHEE-GDSS to assess the alternatives at strategic level. It illustrated the need for inter ministries cooperation in SEA. In all those cases, main contributions from stakeholders relied on building their own weight set according their priorities and values and on negotiation once they completed the appropriation phase of their own results (ranking and others, see Section 3). They all found the set-up of preference functions too complicated, leaving the task to the supporting team after having given the appropriate insights.

Wotto and Waaub (2003; 2006) conducted a pilot project about transport planning for the Montreal metropolitan area. The duration of the project was about 18 months and involved 25 real stakeholders. This project tested a PROMETHEE-GDSS design to be managed on the Web. For the definition of the problem setting a mini policy Delphi approach on the Web was used. MCDA was done in the lab using data collected through a secure Web site. Lessons from this project is that it is always important to have some face to face meetings even if Internet can allow a better contribution by offering asynchronous and delocalized opportunities. Also, training and capacity building might be needed, considering that people do not have similar skills to master Internet exchanges and communication processes.

In Vaillancourt and Waaub (2006), a simulation of international negotiations was performed. The case was on greenhouse gases allocation permit in contrasted climate control policies but extending the stakeholders involved beyond the Kyoto Protocol to all countries grouped into 15 regions. It included also two innovative issues: how to deal with different views of equity, and how to implement dynamic MCDA.

In Morais and Teixeira de Almeida (2007) a common criteria set was used for the whole group. Every stakeholder can choose his/her own weights and preference functions. The judgment of the alternatives is done by the group in an open discussion phase. In order to get a group ranking, the procedure of the PROMETHEE-GDSS method is used and were they gave the different stakeholders a different weight according to their responsibility in the decision process. Also in Alencar and Teixaira de Almeida (2010) PROMETHEE GDSS the preference function were established in an interactive way between the stakeholders and the analyst and are thus also common for the whole group PROMETHEE VI (the brain, see Figure 3) is being used to see if changing the weights of the criteria (and not of the actors!) would significantly influence the decision.

It is interesting to note that the PROMETHEE-GDSS approach can be use either with real stakeholders in complex societal controversies or to simulate stakeholder behaviours depending on who is the “client”.

Behzadian et al. (2011) study the development of a new generation automotive part for a main supplier to a global automotive maker. A Quality function deployment (QFD) is considered in order to facilitate the translation of customer attributes to technical characteristics of the part. This paper proposes a three-phase approach incorporating PROMETHEE GDSS into House of quality, first phase of a QFD. Also the decision makers may play a more important role than others on a certain criterion and each criterion and decision maker are treated as unique in terms of the preference function and threshold levels.

In Turcksin et al. (2011) a combined AHP-PROMETHEE approach is being used for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet. Although it is not a real PROMETHEE-GDSS procedure, it is worth mentioning here. In this application, the Analytical Hierarchy Process (AHP) method was used to obtain the weights for the different criteria. This allows involving the stakeholders in this step of the procedure. The stakeholders (being the car manufacturing industry, user-organizations and policy makers) gave their opinion about the weights and this was brought together with this geometric mean. These weights were then further used in the traditional PROMETHEE method. A discussion in group about the results of the PROMETHEE model was done during a workshop in order to find a consensus on the proposals that were evaluated.

5 SWOT analysis

From the examples above, one can see that PROMETHEE-GDSS has been used in several contexts and in different ways. Based on these experiences, a strengths, weaknesses, opportunities and threats analysis is executed. This SWOT uses the further development of the PROMETHEE-GDSS methodology as its focus and compares PROMETHEE-GDSS with other evaluation methods within the context of GMCDSS.

5.1 Strengths

PROMETHEE-GDSS is usually experienced as a very transparent method and one that can be used without too much interference with the supporting team, although some have difficulties in choosing the preference functions (see weaknesses). The good mathematical foundation (Macharis et al., 1998), together with its several analysis and graphical tools enable the user a thorough analysis of the problem at stake. Of course the possibility to include the stakeholders within the analysis is the main strength of the GDSS module of PROMETHEE compared to any other MCDA methods that do not include such a module. It is possible to switch easily from the individual to a common set of criteria and back. It gives a clear view of each stakeholder and of the group thus providing a strong support for deliberation and negotiation with a sharing common space (Ishizaka and Nemery, 2013). In such processes involving even conflicting issues, it is important that each stakeholder constructs its own appropriation of the problem and solutions that take into account their own preferences, priorities and values. Represent stakeholder's preference is a challenge in itself. Thus the utility functions of the MAUT approach hardly include parameters directly related to stakeholders. By assessing thresholds of indifference and strict preference PROMETHEE provides an easy way to precisely evaluate stakeholders' priorities (Wand et al., 2010).

5.2 Weaknesses

As mentioned above, some actors have difficulties to choose the preference functions and to interpret the outcome of their decision. Although in theory you could say that PROMETHEE-GDSS can be used by any organization who would like to use it, in practice there is a clear need to have a facilitator and or an analyst to facilitate the process, certainly in a GDSS setting. This facilitator should also be able to handle conflicts and discussions about the final outcome of the analysis. More communication tools and guidance to help the facilitator in this task should be developed.

Another weakness of the PROMETHEE-GDSS tool, which is common for most of the GMCDSS tools, is the problem of splitting bias. The structure of the value tree affects the weights (Hamalainen and Alaja, 2008) and by doing so the weight of a certain criterion can be diluted according to its place in the hierarchy. In a splitting bias, decomposing an objective into multiple attributes leads to a higher overall weight for that objective when compared to a direct assessment of the objective's relative importance (Jacoba and Hobbs, 2007). Also other experiments have shown the evidence of biases occurring with the use of value trees. Borcherding and Winterfeldt (1988), for example, demonstrated that weights for an objective tend to be higher when the objective is presented at a higher level in a value tree, while Stilwell et al. (1987) claim that hierarchically assessed weights tend to have a larger variance than weights assessed in a non-hierarchical way. The choice of the criteria weights and of the stakeholders' weights is a crucial point of the methodology.

5.3 Opportunities

Stakeholder management in multicriteria will gain in importance as societal decision makers are facing an important class of problems that involve choices between conflicting objectives such as economic and environmental ones. By their inherent nature they are of interest to a diverse set of stakeholders (Gregory and Keeney, 1994). According to Gamper and Turcanu (2007) decision makers are more likely to choose tools as MCDA when they face decision coupled with uncertainty which is typically the case for sustainability decisions that concern the quality and quantity of future resources. When making wrong decisions, conflicts are likely to arise among the affected stakeholders and decision makers could be blamed by them.

Moreover PROMETHEE can be successfully combined with other MCDA methods. As an example the importance of criteria can be determined by AHP and the ranking of the alternatives by PROMETHEE (Wang and Yang, 2007). This hybrid approach strengthens the procedure with PROMETHEE-GDSS (Turcksin et al., 2011).

Another opportunity for the PROMETHEE-GDSS method is the development of very user-friendly software for it such as D-Sight and the now freely available VISUAL-PROMETHEE. The fact that this software is easily available will result in an increasing number of people using it. Where a constructive approach can be adopted, PROMETHEE-GDSS method and its dedicated software are welcomed and recommended by its users (Ishizaka and Nemery, 2011). This emphasizes also the need for training people at different levels. On the expert side, there is a need to know how to be a good facilitator, how to give better support to the process, how to manage stakeholders, how to communicate results etc. On the stakeholder side, there is a need for capacity building and social learning either about the involved processes or the different tools used (PROMETHEE-GDSS, GIS, Web interfaces etc.).

5.4 Threats

As noted by many authors, MCDA is often been used in a technocratic way, centred on the expert(s) and/or authorities (Gamper and Turcanu, 2007; Munda, 2004; Lotov, 2003; Banville et al., 1998, Bana e Costa and Oliviera, 2002). The experts have the tendency to be more sensitive to the mathematical rigor than to the relevance of the work (Banville et al., 1998). This technocratic (expert-oriented paradigm) is unable to take the points of various interest groups, mass media and even individual citizens into account which want to be involved in important societal decisions. This expert-oriented paradigm is confronted by its limits when protests and criticism alter or even stop the implementation of strategies and measures (Lotov, 2003). Munda (2003) speaks about a new paradigm, within post normal science, in which it is possible to deal with two crucial aspects in the policy domain, namely uncertainty and value conflict. It has been noted for the first point which is typically the case for sustainable decisions, that decision makers are more likely to choose tools such as MCDA, as it concerns the quantity and quality of future resources. It directly relates to the latter, as making wrong decisions in this case, conflicts are likely to arise among the affected stakeholders and the decision makers could be blamed by them (Gamper and Turcenu, 2007). An important issue is then, on how to incorporate these stakeholders within the decision process. If some decision makers might sometimes face temptation to manipulate the process as this has been illustrated by the Arnstein ladder of participation, it is better not using GMCDSS because once they will be involved in such participative and transparent approach, it will be better to face the responsibility for the final decision.

Another threat is still the dominance of socio-economic evaluation tools as social cost-benefit analysis, cost-effectiveness, economic impact analysis (EIA), etc. These instruments have surely their utility, but fail to incorporate the points of view of the stakeholders and restrict the analysis to only specific criteria or

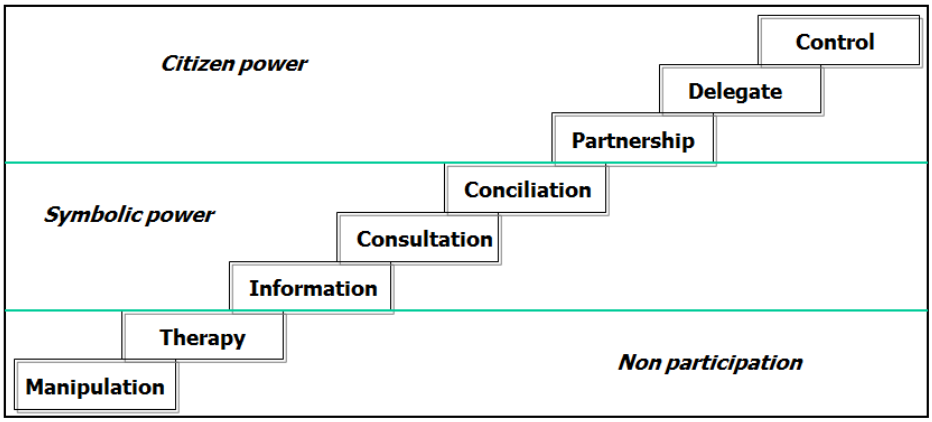

Figure 4: Arnstein ladder of public participation

monetary values. The latter becomes more and more problematic in the context of sustainability. Several objectives are difficult to quantify and certainly to monetize (for example quality of public transport, value of human life, etc.) (Damart and Roy, 2009; Tsamboulas et al., 1999, Scannella and Beuthe, 2003).

Finally the literature review of Behzadian et al. (2010) shows that PROMETHEE has some strengths compared to other MCDA methods' performance. But amongst the MCDA methods themselves, the adoption of the appropriate method between Multi Attribute Utility Theory (MAUT), the Analytical Hierarchy Process (AHP) approach, ELECTRE or PROMETHEE can be delicate (Guitouni and Martel, 1998). The same issues arise within the GDSS context. We believe that much has to do with how well familiarized the researchers or users are with a certain method and feel comfortable using it.

6 Recommendations

6.1 New communication tools

Most important in a multi actor setting is that good communication tools are in place so that the results of the analysis can be communicated but can also serve as a mean to structure the discussion. Within PROMETHEE-GDSS this is usually done with the GAIA plane, which is a nice instrument. However, when many actors are involved, the visualization might not be so clear. In addition, as the GAIA plane is a two dimensional representation of multidimensional data, some information is lost (as indicated by the delta parameter) and it can be more or less reliable depending on the size of the problem and on the degree of conflict. For this reason, other GDSS tools have been implemented in each PROMETHEE software.

As indicated in Macharis et al. (1998), PROMETHEE VI can be used to further analyze the group situation. PROMETHEE VI, also called the decision maker brain in a single stakeholder setting, shows the possible sensitivity of the result. This kind of analysis is possible in PROMCALC and D-Sight as well as in the newer Visual PROMETHEE software but not in Decision Lab.

Besides, the Visual PROMETHEE software introduces several new possibilities. It is possible to have a global overview of the stakeholder points of view by comparing side by side the individual PROMETHEE II net flows. An example is given in Figure 5, with four stakeholders and five alternatives (Site 1 to Site 5). It is a plant location problem whose data are available for download together with Visual PROMETHEE. Each column corresponds to one stakeholder and shows his/her PROMETHEE II ranking. In Figure 5 Site 3 and Site 2 are the most preferred alternatives and that two coalitions of stakeholders can be identified: Industrial and Political stakeholders prefer Site 3 while Environmental and Social stakeholders prefer Site 2.

A next step is to identify the origin of the conflicts between the stakeholders. For this purpose, two additional GAIA analyses can be performed. First it is possible to compare the way the stakeholders have evaluated the alternatives on a single shared criterion. Such an analysis can be used to achieve a better definition of the criteria among the stakeholders and to solve misunderstandings or ambiguities about the definition of the criteria. Another GAIA analysis can be performed on a single alternative to compare the way it has been evaluated by the different stakeholders. This makes it possible to identify potential misunderstandings about the definition of the alternatives. These two analyses are of course only possible if the stakeholders use a shared set of evaluation criteria. They are implemented in Visual PROMETHEE.

Visual PROMETHEE also integrates a 3-dimensional GAIA analysis that can be useful when the GAIA plane has a lower quality (small delta value). The addition of a third dimension makes it possible to increase the quantity of information that is displayed by GAIA (Figure 6).

6.2 New processes: How and when to include stakeholders in the process

As said in Section 2, the inclusion of stakeholders in a GDSS process is very important. However, this is not always well organized. A good way to structure this involvement of the stakeholders can be by adopting the MAMCA methodology. MAMCA stands for multi actor multi criteria analysis. It allows evaluating different alternatives (policy measures, scenarios, technologies, ...) on the objectives of the different stakeholders

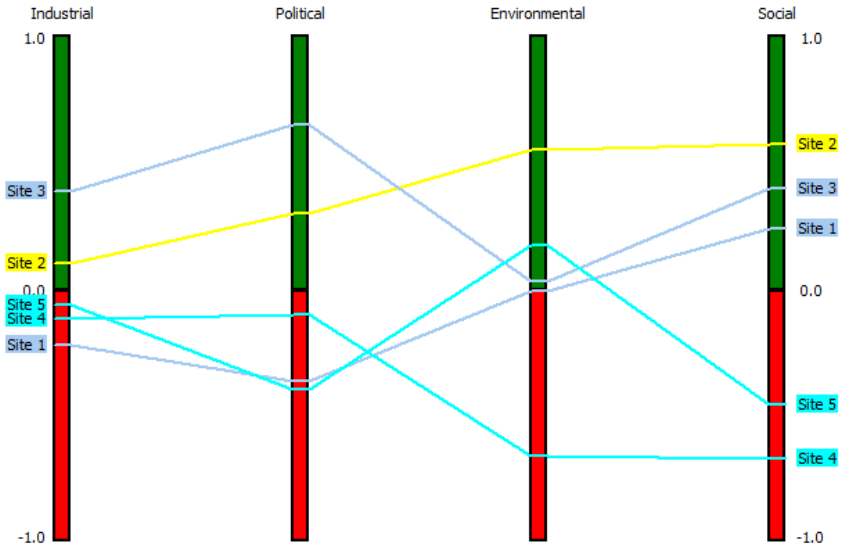

Figure 5: Visual PROMETHEE: Multiple scenarios comparison

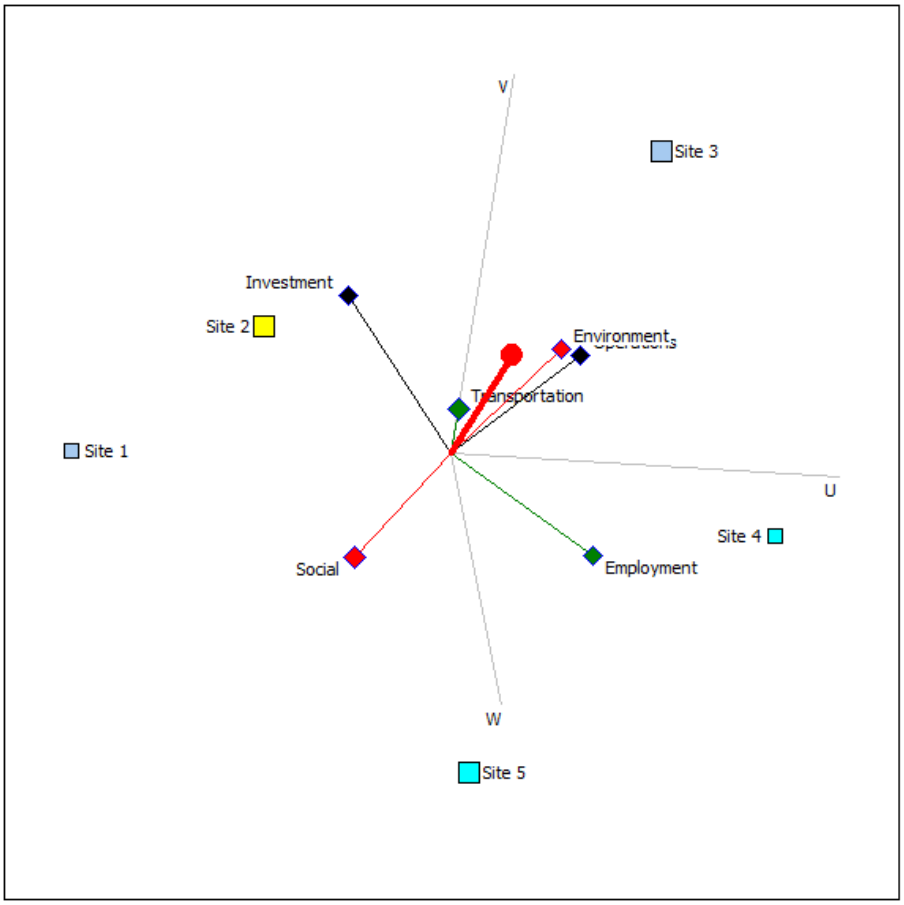

Figure 6: GAIA 3D view in Visual PROMETHEE

that are involved. Unlike a conventional MCDA, where alternatives are evaluated on several criteria, the MAMCA explicitly includes the points of view of each stakeholder.

The methodology consists of 7 steps (as shown in Figure 7). The first step is the definition of the problem and the identification of the alternatives. These alternatives can take different forms according to the problem situation. They can be different technological solutions, different policy measures, long term strategic options, etc. Next, the relevant stakeholders are identified (step 2). Stakeholders are people who have an interest, financial or otherwise, in the consequences of any decisions taken. Thirdly, the key objectives of the stakeholders are identified and given a relative importance or priority (weights) (step 3). These first three steps are executed interactively and in a circular way. Fourthly, for each criterion, one or more indicators are constructed (e.g. direct quantitative indicators such as money spent, number of lives saved, reductions in CO^2 emissions achieved, etc. or scores on an ordinal indicator such as high/medium/low for criteria with values that are difficult to express in quantitative terms etc.) (step 4). The measurement method for each indicator is also made explicit (for instance willingness to pay, quantitative scores based on macroscopic computer simulation etc.). This permits measuring each alternative performance in terms of its contribution to the objectives of specific stakeholder groups. Steps 1 to 4 can be considered as mainly analytical, and they precede the "overall analysis", which takes into account the objectives of all stakeholder groups simultaneously and is more ?synthetic? in nature. The fifth step is the construction of the evaluation matrix. The alternatives are further described and translated into scenarios which also describe the contexts in which the policy options will be implemented. The different scenarios are then scored on the objectives of each stakeholder group. For each stakeholder group a MCDA is being performed. The different points of view are brought together in a multi actor view. This yields a ranking of the various alternatives and reveals their strengths and weaknesses (step 6). Afterwards, the stability of the ranking can be assessed through sensitivity analyses. The last stage of the methodology (step 7) includes the actual implementation. Based on the insights of the analysis, an implementation can be developed, taking the wishes of the different actors into account.

The MAMCA methodology has already proven its usefulness for several transport related decision problems (for an overview see Macharis et al., 2009). The application used the AHP method inside the MAMCA methodology or the PROMETHEE GDSS method. The advantage of the methodology is that it structures the different steps in the evaluation process and allows integrating the stakeholder opinions along the way. The degree to which participation will effectively be obtained depends on the way the different steps are executed. Steps 2 and 3 should be done with a real participation of the stakeholders as here a consensus should exist on the list of stakeholders and each stakeholder group should formulate its set of criteria and

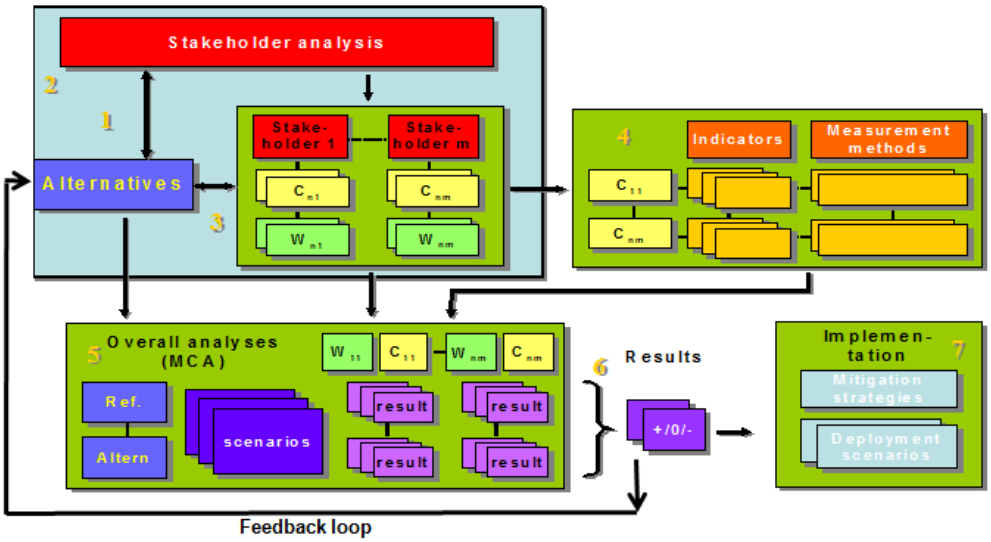

Figure 7: The MAMCA methodology (Macharis et al., 2009)

the weights they are attaching to them. The evaluation itself is usually done by experts but also here the stakeholders can be involved. The discussion on the results (step 6) can also be done very openly and in consensus.

6.3 New knowledge: Role of the facilitator and social learning process

A number of prerequisites related to the good will of the stakeholders to participate into a rational problem solving process involving other parties should be met before applying these approaches. On a collective basis, participants should be open to negotiate, recognize the multicriteria nature of the problem, be proactive to ensure the representativeness of different point of views, accept the help of a supporting team, which in turn should not be invasive and focus on guaranteeing the legitimacy of the deliberations by the mean of a facilitator. The facilitator should not induce conformity to his own suggested framework but should be open to suggestions of all the actors. Each stakeholder should in turn be committed to the process until its end, given time availability, stay open to the results provided by the analysis, and accept that the final result might be counter intuitive or different from what he expected.

Stakeholders should always negotiate some conditions to their participation before the beginning of the process. Those conditions include: availability of training to the process and to the methodological tools used; adapted process to the cultural, political, institutional context; appropriate time frame, budget and human resources available; conflict resolution procedure; facilitator; the steps in which they will be involved; the way the process will influence the final decision (justification of the decision against convergences and divergences, written report, etc.); and the follow-up planned.

It is also very important to define who is legitimate to participate. From the point of view of the decision makers, not only the "good ones" should participate. The process should be considered as giving opportunities for emerging solutions from conflict resolution and negotiation mechanisms. The problem setting is greatly influenced by the interactions between stakeholders. Some actors cannot participate because they are either absent (not in the area, future generations, etc.) or weak (poverty, disabled, etc.). How should they be taken into account? Is simulation acceptable?

As mentioned above, stakeholders can be involved directly in the assessment. Most of societal complex problems need to integrate, unite or find an equilibrium among different types of knowledge such as scientific, traditional (as First Nations), vernacular, contextualized knowledge etc.

Finally, it is important to be conscious that all actors are parts of a social learning process. Web 2.0 gives many opportunities to exchange rapidly and efficiently (even though sometimes the technology looks like creating "noise"). Some community of practice might be very helpful to overcome challenges.

7 Conclusions

PROMETHEE-GDSS has been applied in several applications. The applications show the potentiality of the approach and related methodological tools. PROMETHEE-GDSS has the ability to open up the decision process to all involved actors. An important strength of the methodology is that it enables to include several stakeholders within the decision process. This will become increasingly more important in the future which makes it directly an opportunity. A weakness is that a facilitator should always be there to facilitate the process. We advocate for new and good communication tools to help guide the discussions. Recent software includes several new, built-in tools. In terms of involving the stakeholders, the Multi Actor Multi Criteria Analysis is a good methodology to integrate the stakeholders within the process in a structured way. The role of the facilitator and the social learning process should be given enough attention. Further research will be conducted on how to further strengthen the methodology along the lines of the recommendations of this paper.

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