Montreal, November 3, 2016

Mr Doug Horswill,
Expert Panel - Review of environmental assessment processes

Dear Sir,

In response to your request, please find attached to the present message the schematic of the strategic environmental assessment process used in the case I was referring to in my presentation to the Committee, Tuesday the 1st of November. This process is a direct application of multi actors multi criteria analysis (MAMCA) methods to environmental assessment. I took the liberty to add an article explaining the underlying principles of these methods.

MAMCA methods have been used successfully to manage public controversies aroused by the realization of projects involving environmental issues. I hope this article will interest you. Don't hesitate to contact me for more explanations regarding the subject.

Good continuity in your works.

Best regards,

Gilles Côté

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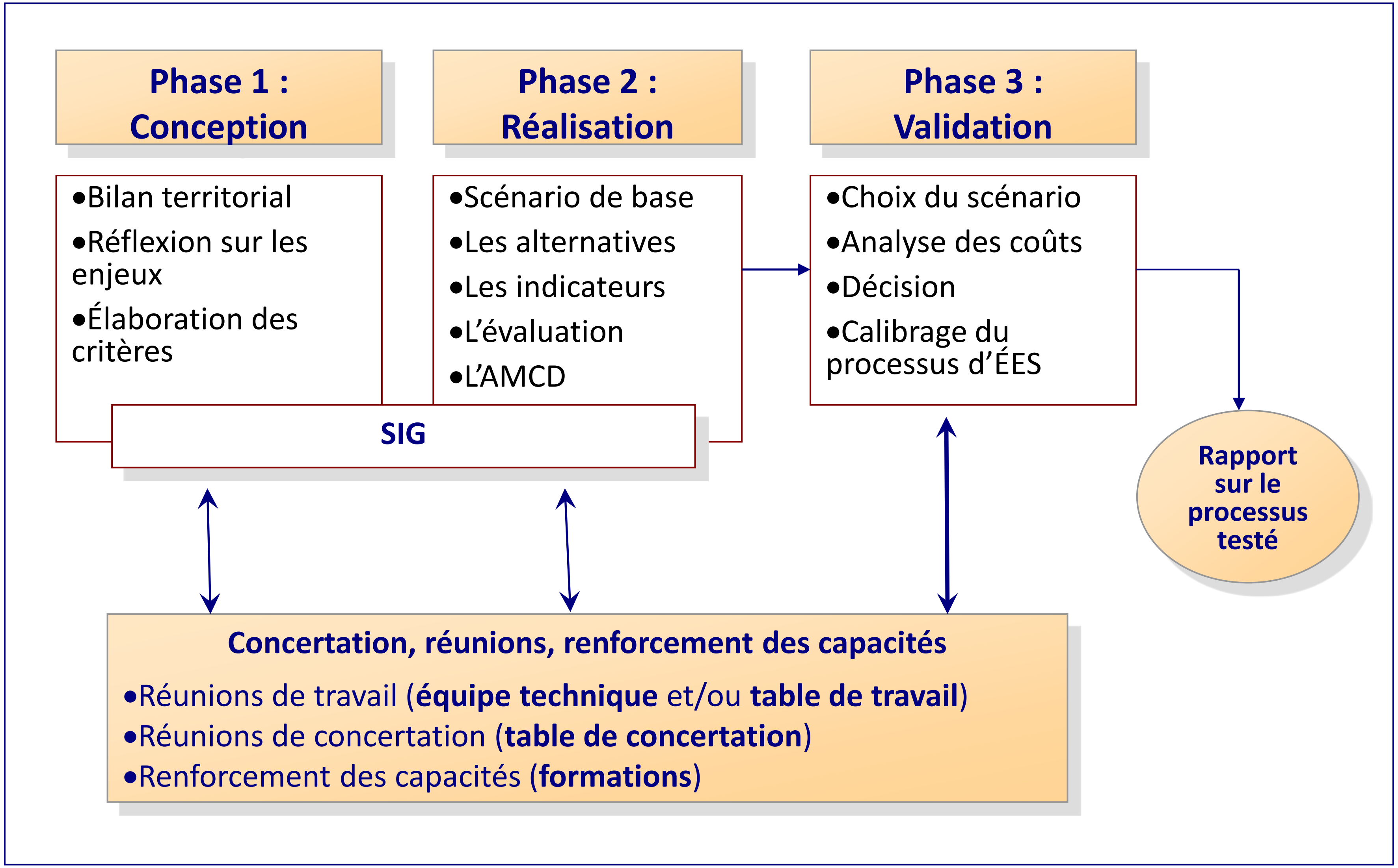
ÉTAPES DU PROCESSUS TESTÉ



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Multi actor multi criteria analysis (MAMCA) as a tool to support sustainable decisions: State of use

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In this contribution, the multi actor multi criteria analysis (MAMCA) to evaluate transport projects is presented. This evaluation methodology specifically focuses on the inclusion of the different actors that are involved in a project, the so-called stakeholders. Like the traditional multi criteria decision analysis (MCDA), it allows including qualitative as well as quantitative criteria with their relative importance, but within the MAMCA they represent the goals and objectives of the multiple stakeholders. As such, the stakeholders are incorporated in the decision process. The theoretical foundation of the MAMCA method is shown, together with several applications in the field of transport appraisal.

1. Introduction

Decision making in transport projects frequently leads to much discussion, controversy and disagreement. In the absence of methodologies that (can) cope with different points of view of stakeholders, projects are often not implemented or lead to unacceptable delays. Transport project decisions can range from infrastructural projects, towards the implementation of road pricing or the choice between different transport technologies. Typically, these are issues where several levels of public policy are involved in (local, province, regional, state and European level) and contain a number of stakeholders (such as freight forwarders, investors, citizens, industry…) which have a vested interest in the ultimate decision. If the study or analysis fails to take these interests into account, it will be ignored by policymakers or attacked by the stakeholders [86].

Currently, there is no widely systematic approach to incorporate these different points of view within the evaluation process of transport projects. Often, cost benefit analysis (CBA) is being used in this field and in some cases cost-effectiveness analysis (CEA), economic impact analysis (EIA) and the social cost benefit analysis (SCBA). These instruments surely have their utility, but they fail to incorporate the points of view of the stakeholders and restrict the analysis to specific criteria or monetary values. The latter becomes more and more problematic in the context of sustainability. Several objectives are difficult to quantify and certainly in terms of monetary values (e.g., quality of public transport, value of human life, etc.) [16,75,80]. The difficulties that arise when measuring all relevant impacts of a project in monetary terms, in particular with respect to intangible aspects and externalities, have led to the complementation of monetary evaluation (unique criterion) with methods using more than one criterion, i.e. multi-criteria methods [80]. Aside from including the abovementioned issues, multi criteria decision analysis (MCDA) also allows the analyst to involve the objectives of different interest groups or stakeholders [7,36,47].

In this paper, we propose to use the Multi Actor Multi Criteria Analysis (MAMCA) for the evaluation of transport projects. In this methodology, which can be seen as an extension of the traditional MCDA, the stakeholders are explicitly taken into account. Moreover, it allows using non-numeric or non-monetary values in the evaluation. First, the use of MCDA and group decision support systems (GDSS) for the explicit inclusion of stakeholders is discussed and a classification is made (Section 2). This classification allows focusing on a particular set of methods and applications that are useful in the field of sustainable transport, mobility and logistics. These applications will be discussed in Section 3. In Section 4, the MAMCA is briefly presented and the different applications in which it was used are listed. Next, the different steps of the methodology are explained in more detail and the lessons learned within the applications are shared.

2. Multi criteria group decision making: a classification

The concept of stakeholders was introduced in the research field of strategic management [90]. These stakeholders needed to be taken into account due to the fact that firms were focusing more and more on corporate social responsibility [13,19]. Freeman [27] 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. [7] who makes a very convincingly plea for the

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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 being affected by it and 3) by both affecting it and being affected 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 [62] 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 come together on the discussion table. In the definition of Grimble and Wellard [31], 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". However, we prefer to delete "common interest" as this leaves the door open for any person or group who, by merely intellectual curiosity, would like to be involved in the decision process. 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 [31] 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) [31]. Similar to the concept of stakeholders MCDA,) most multi criteria group decision making (MGDM) methods were also developed for group decisions within an organizational/business context (for an overview, see Álvarez [3]). In this context, the aim is to get a common view on the problem in a quite homogeneous group. This can be seen in the different steps of the methods and the way the individual results are aggregated. Let us take the example of the widely used the analytic hierarchy process (AHP) method (developed by Saaty [71] and extended for group decision support by Dyer and Forman [23]. Within AHP, Saaty advocates the use of consensus voting in order to come to a common pairwise comparison matrix for the whole group or to aggregate the individual judgments. This aggregation can be done by computing the geometric mean of the individual pairwise comparisons and by constructing with these geometric means a new pairwise comparison matrix and then computing the 'eigenvector' of the positive reciprocal matrix [2][1]. It is also possible to use the weighted arithmetic mean method, where the average of the individual pairwise comparisons is computed. In this method, it is possible to use weights so that decision makers can be attached more or less power depending on their knowledge and expertise. In Basak and Saaty [8] a third possibility is added for geographically separated groups for which a statistical method can be used in order to find homogeneous (sub)groups.

In all these approaches a common hierarchy (or in other words a criteria set) for all the decision makers is considered. The group is assumed to be homogeneous [65], 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, namely to create more value for the firm. 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 multi criteria analysis (SMCA) as defined by Munda [62] exactly 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 [62]. A common value tree/hierarchy/criteria set in such a context is not possible.

So the difference between the MGDM 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 [43] do. Or one can also make a difference between models with the same value tree for all stakeholders (or decision makers) or with different value trees for each stakeholder [17]. 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. If several individual value trees exist and are only aggregated in the end, we talk about output level aggregation. In the evaluation of transport projects it is important to distinguish the different points of view, hence different value trees and output level aggregation are most appropriate.

So we are searching for methodologies or applications in the field of SMCA in which several individual value trees can be used (see Table 1). In the next section, the literature review will concentrate on this subdomain.

3. Applications of social multi criteria analysis with several value trees for the different stakeholders

SMCA has been well developed in the field of environmental decision making (for an overview of the use of MCDA in environmental decision making see [34,67]). Also the idea of integrating stakeholders within the decision process is well established (see for example [31]). Most of the applications try to find a common value tree or criteria set for these stakeholders (this is the case in [1,4,11,25,32,78]). In Lotov [45] an attempt is made to make environmental decision making more democratic by using internet based tools (e-democracy). Very often the problem is merely to combine the expertise of the different actors in the evaluation process, as stakeholders are often seen as experts in the field of environmental decision making. This is also the case in safety planning. In the study of Rosmuller and Beroggi [68], the stakeholders had to evaluate the alternatives on all objectives. However, according to their level of expertise, these evaluations were weighted within the overall evaluation. The weights of the actors were elicited by pairwise comparisons by the stakeholders themselves. Similar applications of participatory expert decision making in safety planning include Beroggi and Wallace [9], Rosmuller et al. [69] and Timmermans and Beroggi [79]. A criticism that is often encountered in SMCA is the existence of several policy levels that are involved. In McDaniels et al. [59], these different levels are described together with their objectives, but this is not followed by a MCDA. Within the field of transport, most applications work towards a common set of criteria (so one value tree for all stakeholders). In Bana e Costa [5], a common criteria set is constructed for the three stakeholder groups (municipality of Lisbon, Railway Node Bureau, Portuguese Railway Company) to analyze the different possibilities for the construction of a new railway link to the port of Lisbon. In Perçin [64], an evaluation of 3PL providers is elaborated by a combination of the AHP method for the weights and the technique for

Table 1
Classification of multi criteria group decision making (source: own setup).

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

[1] There has been a vivid discussion about the use of the geometric mean method. Ramathan and Ganesh (1994) have argued that it does not satisfy the pareto optimality axiom. Van den Honert and Lootsma (1996) showed that the pareto optimality is not related to any defiency of the geometric mean method. As the final aggregation is a compromise between all members, this violation could be expected.

order preference by similarity to the ideal solution (TOPSIS) for the final ranking. A Delphi method helped the several experts come to a common criteria hierarchy, which was used for all evaluations. Scannella and Beuthe [76] have structured the problem together with the decision makers, including the determination of the relevant criteria. The decision makers (in this case the provincial directors) were asked for a consensus about the criteria set and to assign weights to the several criteria. In Jakimavicius and Burinskiene [35], a combination of a geographic information system (GIS) with TOPSIS and the simple additive weighting (SAW) technique is applied to localize problematic transportation zones in Vilnius City, Lithuania. The weights of the criteria used in their analysis were based on the input from questionnaires filled in by various experts.

AHP is also extended for group decisions [73]. Sharifi et al. [77] developed a slight variation of AHP for assessing public transport and land use planning. They identified two groups of stakeholders, the planning and political oriented side and the technical side, to give input information on criteria and alternatives. The stakeholder specific decision data were afterwards aggregated using a weighted linear utility function in the process of a MCDA. In Filippo et al. [26], stakeholder participation is introduced by applying the techniques of fuzzy set theory combined with AHP. Based on this technique, the analysts were able to include information from experts and specialists for ranking highway restoration alternatives with a focus on environmental sustainability. The involved stakeholders were the government and the highway authorities, and their input was also used for the assignment of the criteria weights. However, the actual evaluation of the alternatives for the criteria was based on results from previously carried out studies and research and was thus not founded on stakeholder input. Another transport project where the fuzzy technique is used is the one described by Wey and Wu [89]. In this, mainly theoretical, paper, the fuzzy technique is combined with the analytic network process (ANP) and goal programming. This combined technique is designed to take into account the different criteria, the relations between them and the opinions of various stakeholders. Stakeholder participation is acquired through interviews and used to define the type, importance and interdependence of the various criteria. Chen et al. [14] combined GIS with AHP to select the optimal route for nuclear waste transport in Taiwan. Five different stakeholder groups were included in this study: the Institute for Nuclear Energy Research (INER), the police department, a medical expert, a group of transporters and a professor in nuclear energy who has to embody the interests of the community. Each of the groups separately defined the weight of the three predefined criteria through the pairwise comparisons of the AHP technique. Afterwards, the computed weights were averaged to a global weight per criterion. Based on the evaluation of the different alternatives for these weighted criteria, an optimal route was calculated by the GIS application for each criterion separately and for the combination of the three criteria.

Overall, in all these cases, a common value tree for all stakeholders is constructed. This is also true for the following applications, but, in contrast to the ones mentioned above, more effort has been put in further keeping the stakeholders within the decision process (in the later stages of the process). Berrittella et al. [10], for example, evaluated different transport policies for reducing the climate change impact caused by greenhouse gas emissions. They involved nine experts into the AHP analysis by letting them pairwise compare the predefined criteria, which resulted in the assignment of different weights. Afterwards, the experts also needed to pairwise compare all the alternatives for each criterion, which resulted in the final ranking of the alternatives.

Tuzkaya [84] used a combination of fuzzy AHP with the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE, developed by Brans [12]) for choosing the transport mode that minimizes the negative effects on the environment of the Marmara region in Turkey. In this transport project, stakeholder participation was a crucial aspect in the entire analysis. First, a decision making group, with representatives from the government, local authorities, academics, environmental organizations and logistic firms, were encouraged to come to a consensus about the different criteria and alternatives. Afterwards, the fuzzy AHP was used by the stakeholders for defining the weights of the different criteria. For the actual evaluation and ranking of the alternatives, as well as for the comparison between the two methods, two PROMETHEE tools (PROMETHEE I partial ranking and PROMETHEE II complete ranking) were applied, together with further input of the stakeholders. The ELimination Et Choix Traduisant la REalité (ELECTRE) technique is used in Labbouz et al. [39] for implementing a public transport line in France. In the start-up phase of the analysis, much time and effort was devoted to make a dialog possible between the different stakeholder groups (decision makers, builders and a mixed group of involved stakeholders) and the analysts. Through group discussions and revision of prior results and priorities, the analysts tried to achieve as much consensus as possible regarding the criteria. Afterwards, different ELECTRE TRI analyses were carried out until the end for the various groups of stakeholders. In the end, the obtained results of each MCA were discussed again with all the stakeholders in order to reach a consensus on the decision that needed to be taken. Mousseau et al. [61] recognized the importance of participation of direct and indirect stakeholders in the development of a decision aiding tool for public transport ticket pricing evolution in the Paris Region. Their main concern was to arrive at collectively more acceptable results: rather than requiring a fit-to-use result from the analysis, they focused on a valuable and constructive dialog between the different stakeholders during the entire decision process. They included several stakeholders in the study process, especially for building the set of criteria and determining the indicators but they maintained one MCA for the whole decision problem. Keshkamat et al. [38] also gave a very high priority to stakeholder participation in their project concerning the spatial decision support system for the Via Baltica project in Poland. The authors developed the so-called spatial multi-criteria analysis. They did not apply one specific MCA method, but used instead various MCA techniques such as goal programming, maximum functions, attribute functions, etc.

This overview shows that the notion of stakeholders and their importance in the decision process is reflected in several applications of environmental and transport project appraisal. Most applications apply input level aggregation, where a common value tree and even common weights are given by all stakeholders. This implies much discussion and in many controversial transport project evaluations a common input will not be reached. Therefore, we developed a methodology in which stakeholders are involved and in which their points of view are explicitly taken into account without their being asked to converge directly to a consensus. This methodology is called the multi actor multi criteria analysis, in short MAMCA [53,54]. In the next section, the MAMCA methodology is briefly described together with its applications.

4. The MAMCA methodology and its applications

The MAMCA allows evaluating different alternatives (policy measures, scenarios, technologies…) on the objectives of the different stakeholders that are involved. Unlike a conventional MCA where alternatives are evaluated on several criteria, the MAMCA explicitly includes the points of view of the different stakeholders.

The methodology consists of 7 steps (as shown in Fig. 1). 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 in several transport related decision problems. It was used to cope with an intermodal terminal location decision problem [46], for a study on the choice between waste transport alternatives in the Brussels region [48], for the location choices of a new high speed train terminal [60], for the evaluation of different driver assistance systems in the ADVISORS project [53], in the development of the master plan of the Port of Brussels [21], for the evaluation of DHL's hub strategy at Brussels airport [20,22], in the project 'Night Deli' for the evaluation of different night distribution scenarios [85], in the Flanders in Action Process to structure the discussions on how to turn Flanders into a top region by 2020 in terms of logistics and mobility [55], in the choice of different biofuel options in Belgium [82], in the assessment of spatial data infrastructure strategies [29], the choice between different options for the Oosterweel connection [49], for deriving implementation priorities for innovative road safety measures [18] and for the evaluation of stimulating measures for the purchase of more environmental friendly vehicles [42].

Currently it is used for the choice of light rail implementation scenarios, the assessment of spatial data infrastructure strategies and the evaluation of road pricing schemes.

These diverse applications have taught us much on how to further optimize the MAMCA methodology. In the following section, an overview of the methodology is given as well as a description of how the different steps can be executed with reference to above applications and experiences.

5. The different steps of the MAMCA and lessons learned

5.1. Step 1: defining the problem and the alternatives

The first stage of the methodology includes the identification and classification of the possible alternatives submitted for evaluation. Alternatives can take various forms according to the problem setting. They can range from the evaluation of policy measures in passenger and freight transport to technological solutions, infrastructure investments, location analysis, policy measures with long-term strategic options, and so on. For comparing purposes, a reference alternative can be added to the evaluation process to provide a benchmark against which the other alternatives can be compared.

In cases where the alternatives are pre-determined, the selection of alternatives is done in a straightforward way. In other situations, a broad range of alternatives, which can possibly be tracked from an extensive literature overview, can be screened in terms of their feasibility from a technical, environmental, legal and/or economic point of view. This screening can be done through risk analysis (e.g., the ADVISORS case in [53]) or through an early involvement of stakeholders (e.g., [5,76,83]),

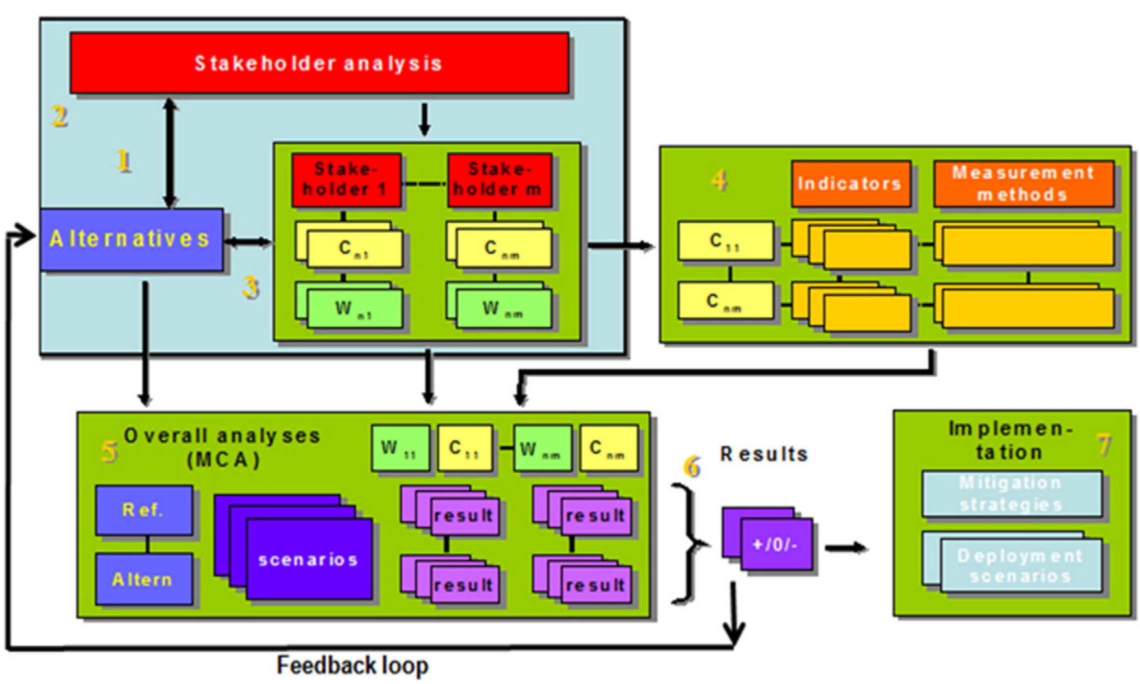

Fig. 1. The MAMCA methodology [54].

potentially combined with an insight into the stakeholders' objectives (e.g., the Oosterweel case in [49]). An early involvement might not only stimulate discussions and help decision-makers to understand the problem, their priorities and those of the involved stakeholders, but it will also considerably help to enhance the acceptance of the final result [7,28]. In that case, steps 2 and 3 of the MAMCA methodology will precede the first step, which highlights their strong interconnection (see Fig. 1).

5.2. Step 2: stakeholder analysis

The stakeholders are identified in the stakeholder analysis. A stakeholder can be defined as the range of people who are likely to use a system or be influenced either directly or indirectly by its use [50]. In other words, stakeholders are people who have an interest, financial or otherwise, in the consequences of any decisions taken. An in-depth understanding of each stakeholder group's objectives is critical in order to appropriately assess the different alternatives. Stakeholder analysis should be viewed as an aid to properly identify the range of stakeholders which needs to be consulted and whose views should be taken into account in the evaluation process. In scientific literature, there are some methods described in order to come to an appropriate list of stakeholders. Munda [62] claims that by an analysis of historical, legislative and administrative documents, complemented with in-depth interviews with locals and other interested parties, a map can be made of the most important social actors. In Banville et al. [7] one can find some formal methods to identify stakeholders: the 7 procedures of Mason and Mitroff [58], the identification of potential reasons for people to mobilize around any aspect of the problem by Weiner and Brown [88], the distinction between external stakeholders, corporate and organizational stakeholders by Savage et al. [75], and the classification by Martin [57] of 7 factions: family, friends, fellow-travelers, fence sitters, foes, fools and fanatics. Only the second method [88] is not explicitly developed for organizational decision contexts. When using the MAMCA the approach of Munda [62] and/or Weiner and Brown [88] is a good start. Next, one should clearly define the (physical) border of the transport problem. How far does the project impact reach? At that moment, one knows which policy level (commune, province, region, country, European, worldwide) should be included as governmental actors. In some cases, it is possible that several levels have to be explicitly taken into account (such as in the case of the Oosterweel decision where the Flemish government had other objectives than the city of Antwerp [49]). After that, one can try to see if there is a demand and supply side of the problem at stake. For example, when evaluating driver assistance systems, we incorporated the manufacturers on one hand and the users on the other hand [53]. One can also take a supply chain perspective, like in the biofuel case, where all actors from the supply side were included (the agricultural sector, biofuel convertors, fuel distributors, end users, car manufacturers, government and NGOs & North–south organizations [81]). Once certain stakeholders are identified, they can be asked, according to them, who should also be involved. So, although there are no strict rules on whom to include [7], it is important to see that all actors who could be affected or can affect are in the list of stakeholder groups. Even if they cannot organize themselves, or one cannot elicit weights from the criteria, they should be included and be taken into account because it would be unethical to leave the unorganized groups out of the analysis. Munda [62] gives the example of people from the rain forest. Should they be forgotten because they might have no official representatives? Or because it is not possible to organize a survey among them? So indeed, they should be incorporated as important stakeholders.

Usually, stakeholder groups will be involved and not single stakeholders. The supply side of driver assistance systems will for example encompass different car manufacturers and manufacturers of the systems themselves. In case of biofuels, feedstock producers are not represented by the agricultural sector or biomass based industry alone, but also by the wood sector, waste processors and traders. A good criterion to see if a stakeholder belongs to a certain stakeholder group is if the same objectives appear in their criteria tree. Within a certain stakeholder group we expect the group to be homogeneous in the sense that they agree on the same criteria. Possibly the priorities and weights might differ a little, but the same criteria tree is used within the stakeholder group. The homogeneity of the group is important, as the weights given by the different members of a stakeholder group will be aggregated by the geometric mean (in case AHP is used) or the average. If the weights given by the stakeholders within a stakeholders group differ much, a sensitivity analysis should be executed in step 6.

5.3. Step 3: Define criteria and weights

The choice and definition of evaluation criteria are primarily based on the identified stakeholder objectives and the purposes of the alternatives considered. A hierarchical criteria tree can be set up. In the MAMCA methodology, the criteria for the evaluation are the goals and objectives of the stakeholders, and not the effects or impacts of the actions per se as is usually done in a MCA. In a natural way, these impacts will be reflected in the goals of the stakeholders (if all relevant stakeholders are included). Munda [62] states that the technical formulation of the criteria can be best performed by the researchers, as they should take care of some properties of the criteria, such as non-redundancy, legibility, and so on. Most of the time, this is pursued by an interactive discussion with the stakeholders in order to come to a particular set of criteria for that stakeholder group. Generally, for each stakeholder group, we first track a preliminary criteria list based on the literature and knowledge of the problem at stake. Next, during interactive discussions with stakeholders (e.g., by telephone, workshops, etc.), each stakeholder group gets the opportunity to evaluate and validate the pre-defined criteria. Here, it is important to come to an agreement on the exact meaning or definition of the criteria that are withheld in order to enhance the common understanding of the criteria tree. At this point, it is also possible that the analysts notice that a specific stakeholder group has no common idea on the objectives and that this stakeholder group has to be split.

Fig. 2 shows an example of a criteria tree. At the left the global objective of the analysis is shown. Next, the different stakeholder groups are listed, together with their objectives. If necessary, the tree is expanded with additional sub-criteria for a further detailing of the objectives.

The weights are then determined by the importance the stakeholder is attaching to (each of) his or her objectives. For the determination of the weights, the existing methods can be used such as the allocation of 100 points, trade-off, direct allocation, and so on (for an overview see [24,63]).

Wang and Yang [87] performed a study on the theoretical validity, predictive and perceived performance of three multi-attribute weight measurement methods using multiple criteria: Saaty's AHP [72] and Edward's simple multi-attribute rating technique (SMART) compared to Anderson's functional measurement (FM) as a theoretical validity standard (see also [91]). AHP was perceived as an equally valid method as SMART and FM, but in terms of perceived performance, AHP is significantly preferred and perceived as easier to use.

In AHP, the relative priorities of each element in the hierarchy are determined by comparing all the elements of the lower level against the criteria with which a causal relationship exists. For this purpose, decision making software packages such as Expert Choice based on Saaty's AHP can be used. Besides Expert Choice, other decision support software packages like ERGO, 1000Minds or M-Macbeth by Bana e Costa et al. [6] can also be used to perform pairwise comparisons. Table 2 illustrates the Saaty scale used for pairwise comparisons.

Fig. 3 shows how the online pairwise comparison survey might look if Expert Choice is used in this step. This illustration shows that each stakeholder had the opportunity to indicate his or her preference

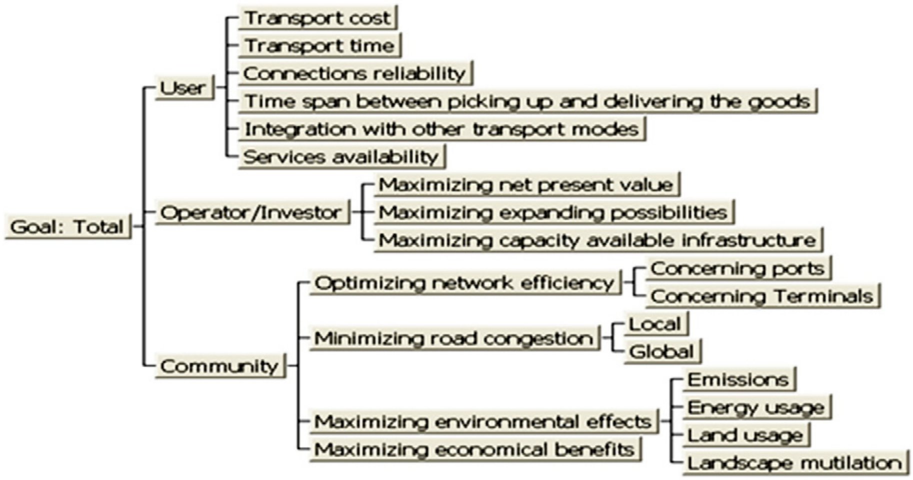

Fig. 2. Criteria tree [46].

intensity for a specific pair of criteria in a user friendly environment. By means of the rectangular bars, stakeholders could attach different gradations of importance, ranging from extremely more important to extremely less important.

Besides AHP, other MCA techniques are also suited to perform the MAMCA. However, in cases where PROMETHEE is used, no specific guidelines yet exist to determine the weights. PROMETHEE only assumes that the decision maker is able to weigh the criteria appropriately, at least when the number of criteria is not too large. That is why Macharis et al. [52] proposed to combine the weight elicitation of AHP with the PROMETHEE method. Applications of this combined technique can be found in [15] and in [83].

The approach followed within the MAMCA for the identification of the criteria and the weights, by approaching it from a stakeholder's perspective, allows looking in another way at the composition of the criteria set. In MCDA-theory, additive methods will lead to double counting if there is a functional relationship between the criteria. Within the MAMCA, the criteria are representing the objectives of the stakeholders. The stakeholders should see which weights they want to attach to these objectives, irrespective if there is a relation between them. Overlap between objectives should nevertheless be avoided in this case.

A new problem occurs however. When creating an extra layer of different stakeholders in the analysis, it is often felt necessary to attribute weights to the stakeholders. This issue is extensively discussed in the literature [37,62,66,70]. In all the MAMCA applications so far, a pragmatic approach is followed and all stakeholders were given an equal weight in order to express that we respect each point of view on an equal basis. Often, a sensitivity analysis is performed on these weights, which can lead to new insights. When the government is one of the stakeholders, which is usually the case in the evaluation of transport projects, one could say that this stakeholder represents the society's point of view and therefore this should be the one to follow. Analysis of the points of view of the other stakeholders, like users, local population, manufacturers, and so on, will then show if a certain measure will possibly be adopted or rejected by these groups.

Before proceeding to the next steps, it is important to stress that the first three steps of the MAMCA methodology are very much interlinked and should be seen as circularly interlinked until all stakeholders, all alternatives and all criteria are identified. At first, a certain idea of the problem will lead to some idea of policy measures that can tackle this problem. Out of this refinement of the problem statement a first idea on the actors who have a stake in the problem at hand will come up. These actors will have new ideas on other problem solutions and moreover an analysis of their objectives might generate new alternatives (see, for a description of the latter, [30]). This circle will go around for a while, usually very entangled. As rightly stated by Landry [40,41], the problem is not an autonomous reality out their waiting to be discovered, but rather a construction stemming from interaction between one or many subjects and the reality upon which the subjects wish to act.

5.4. Step 4: criteria, indicators and measurement methods

In this stage, the previously identified stakeholder criteria are 'operationalized' by constructing indicators (also called metrics or variables) that can be used to measure whether, or to what extent, an alternative contributes to each individual criterion. Indicators provide a 'scale' against which a project's contribution to the criteria can be

Table 2
The Saaty scale for pairwise comparison [74].
Source: Saaty, 2008.

	Definition	Explanation
1	Both elements have equal importance.	Both elements contribute equally to the criterion considered.
3	Moderately higher importance of row element (RE) as compared with column element (CE)	Experience and judgment reveal a slight preference for RE over CE.
5	Higher importance of RE as compared with CE	Experience and judgment reveal a strong preference for RE over CE.
7	Much higher importance of RE as compared with CE	RE is very strongly favored over CE, and its domination has been demonstrated in practice.
9	Complete dominance in terms of importance of RE over CE	The evidence favoring RE over CE is of the highest possible order of affirmation.
2, 4, 6, 8 (intermediate values)		An intermediate position between two assessments
1/2, 1/3, 3/4,…1/9 (reciprocals)		When CE is compared with RE, it receives the reciprocal value of the RE/CE comparison.
Rationals: ratios arising from the scale		If consistency were to be forced by obtaining n numerical values to span the matrix
1.1–1.9: for tied activities		RE and CE are nearly indistinguishable; moderate is 1.3 and extreme is 1.9.

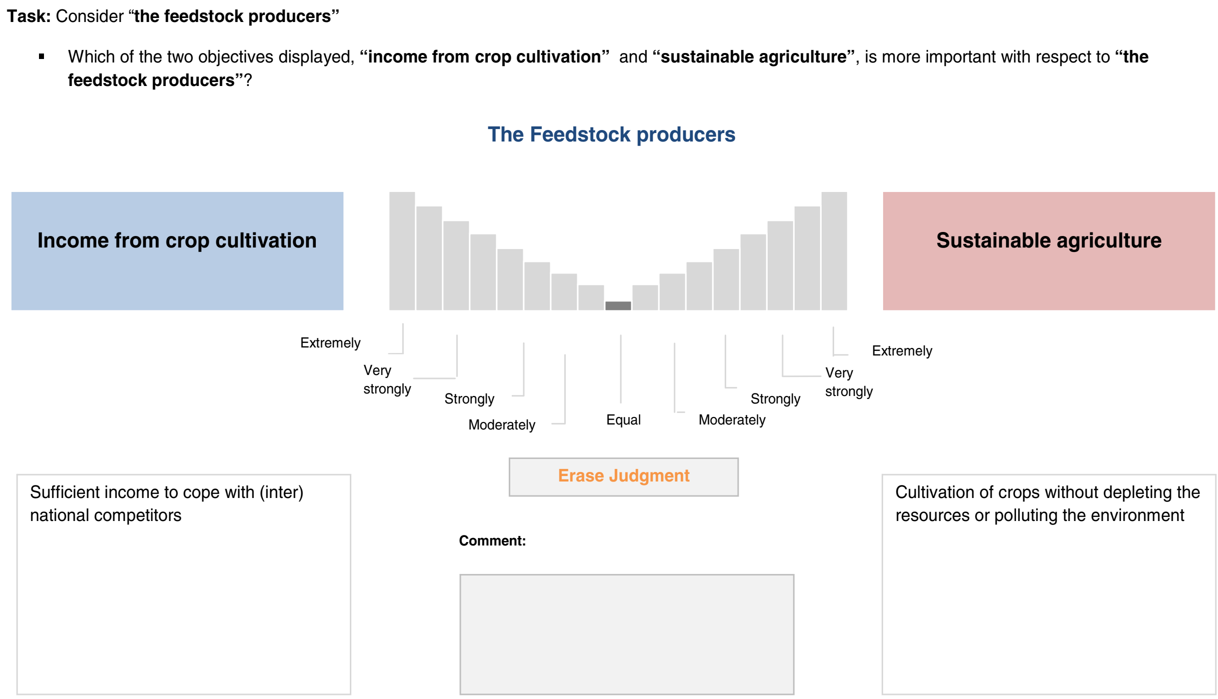

Fig. 3. Screenshot of Expert Choice software [82].

judged. Indicators are usually, but not always, quantitative in nature. The indicator construction follows several stages, as indicated by Fig. 4.

In the first step, the choice of the criterion is made for which the indicator will be built. Next, the indicator is constructed that allows measuring the contribution of each alternative to that specific criterion (step 2). Subsequently, in step 3, the measurement method (quantitative or qualitative) is made explicit. Based on literature and/or expert consultations, each alternative performance can be measured in terms of its contribution to the specific criterion (step 4). By letting experts assign the performance values, a scientific and solid foundation in the evaluation process of alternatives is provided. Finally, in step 5, pairwise comparisons of the alternatives with respect to the specific criterion can be made (e.g., when using AHP, see Table 2), or the information can be directly included in the evaluation matrix (e.g., when using PROMETHEE or other outranking methods). Other MCDA methods can be used as well. This will eventually lead to the construction of the evaluation matrix (see step 5 of the MAMCA methodology below).

5.5. Step 5: overall analysis and ranking

In this step every alternative (from step 1) is evaluated on the different criteria by use of the indicators and measurement methods (step 4) and this for each stakeholder (step 2). It is possible, that in order to get a clear evaluation, the alternatives first have to be translated into scenarios. Scenarios are more broadly defined alternatives in which also the environment in which the alternatives are evaluated is stipulated. If for example one is comparing different driver assistance systems, it is important to define in what kind of setting these systems will be used, e.g., which types of road, assumptions on the penetration rate on the market, etc. to get a proper idea on how these systems will impact the criteria, for example, road safety. To give another example, if one is evaluating different biofuel options, more information has to be given about the broad socio-economic environment in which these policy measures will be implemented.

Once these scenarios are clearly defined, an evaluation table for each actor can be set up and completed. There are multiple ways to

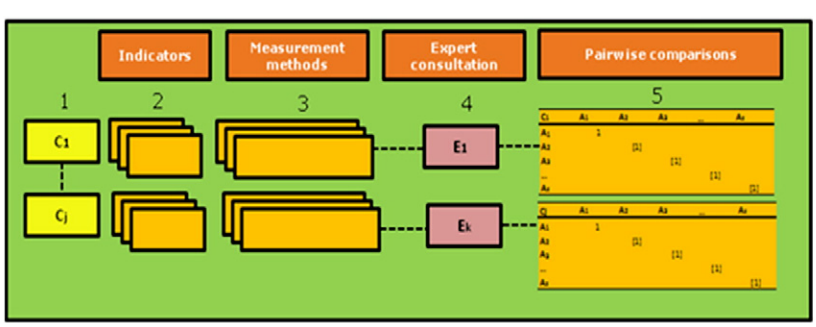

Fig. 4. Indicator construction [82].

make the evaluation of a scenario on a criterion. The analyst (approach 1), the experts (approach 2) or the stakeholders (approach 3) can give the input for the evaluation. The first approach was used in the first applications (such as in [46,48]). One could say that the analyst can try to acquire the necessary expertise on the problem situation in order to make a proper evaluation. As most of the decision problems are multidimensional and also multidisciplinary, it is preferable to cooperate in this step with an interdisciplinary team of experts. These experts can give a scientific grounded (by studies, research, papers…) evaluation of why a scenario should be preferred against another. This gives a good, objective and solid basis for further analysis (see for example the case of biofuels in [82] in which the whole project team combined its multidisciplinary knowledge to fill in the evaluation matrix). The third approach, in which stakeholders are allowed to give their judgments, is also possible but may give rise to a strategic bias. As the stakeholders have already been able to express their objectives and their relative importance (step 3), a further inclusion of their judgment on the evaluation of the scenarios might provide a possibility for them to influence the decision towards their strategic ultimate outcome. However, their opinion is still important in this step. In this regard, even if approach 1 or 2 is followed, the stakeholders should also validate the input given by the analyst or the experts. In cases where the MAMCA is used as a tool to estimate the support for certain measures, the second approach is the most preferred one. In that case, one does not want to know how each scenario scores on the points of view of the stakeholders, but one wants to know what the support of each stakeholder is and in that sense it also includes his/her perception (see for an example the case of night distribution in [85]).

In this step, the evaluation of the alternatives should be inserted in the evaluation table. Once the table is filled in, any MCDA method can be used to assess the different strategic alternatives (such as AHP, PROMETHEE, MAVT, ELECTRE, MACBETH, etc.). In fact, the second generation MCA methods, the group decision support methods (GDSM), are well suited for use in the MAMCA methodology. The PROMETHEE method has, for example, been extended in Macharis et al. [51], the AHP method in Saaty [73] and ELECTRE in Leyva-López and Fernández-González [44]. These GDSM methods give each stakeholder group the liberty of having their own criteria, weights and preference structure and only at the end of the analysis are the different points of view confronted. Mostly the AHP method and the PROMETHEE–GDSS method are used within the MAMCA methodology. Both are widely used for the evaluation of transport projects and they have interesting visual aids to show the points of view of each stakeholder. This will be further discussed in the next step.

5.6. Step 6: results and sensitivity analysis

The MCA developed in the previous step eventually leads to a classification of the proposed alternatives. More important than the ranking, the MCA reveals the critical stakeholders and their criteria. The MAMCA provides a comparison of different strategic alternatives, and supports the decision-maker in making his final decision by pointing out for each stakeholder which elements have a clearly positive or a clearly negative impact on the sustainability of the considered alternatives [54]. In the following paragraphs, two examples will be given where the MAMCA has been used with a different MCA technique, namely one with PROMETHEE and one with AHP.

In Fig. 5 a multi actor view within the PROMETHEE method is shown. The GAIA plane (geometrical analysis for interactive aid) displays graphically the relative position of the alternatives with regard to the criteria and the conflicts between the criteria according to the principal component analysis [51,56]. It clearly shows which points of view are in disagreement, which ones could possibly come to a consensus, etc. For each actor also a uni-actor analysis can be shown, which displays the particular points of interests of that specific stakeholder.

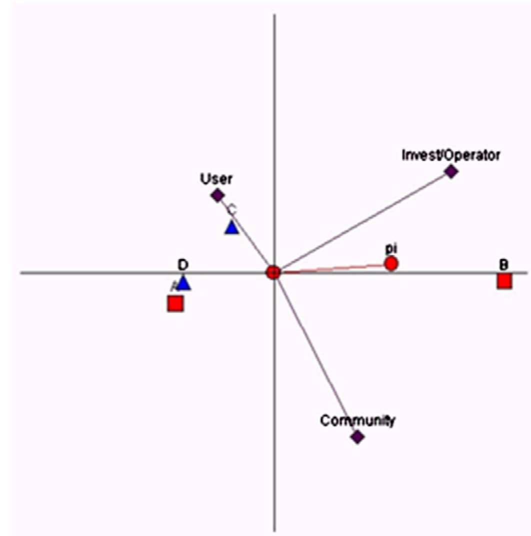

Fig. 5. The multi actor GAIA plane [46].

In Fig. 6, an example is given of a multi actor view in AHP. The graph (which can be found in Expert Choice as a sensitivity graph called performance), shows directly who finds which alternative the most preferred one. If the weights of the decision makers are important it will also be easy to see, which stakeholders have which weight (the rectangles) at the bottom. The only disadvantage from this screen is that the overall axis might suggest that the final ranking will also lead to the best solution. We think this is absolutely not the aim of the MAMCA which is to provide insight in what is important for each stakeholder and not to just sum up these different points of view and come to a final decision. So this last axis, with the 'overall result' should always be commented with care and needs refinement with respect to its visualization if it is used in the context of the MAMCA.

5.7. Step 7: Implementation

The results of the analysis provide the researcher with valuable information which can be used to formulate policy recommendations towards the decision maker, which is very often a public authority. These recommendations are defined to help the decision maker in the search for a deployment scenario which can be generally accepted by every stakeholder. In this respect, two approaches could be followed.

In a first approach, one could say that the public authority represents society's point of view and therefore this should be the one to be followed. The analysis of the points of view of the other stakeholders will then show if the 'chosen' policy measure of the public authority will be supported or not by the involved stakeholders. The government can then choose to implement the 'chosen' policy measure with supplementary measures in order to circumvent the potential barriers from the other stakeholder groups. For example, in the case where several biofuel options for Belgium were evaluated (see Turcksin et al. [82]), the government's preferred option was to implement 'biogas', while this option was clearly rejected by the end-users as a result of higher cost and lower user friendliness considerations associated with this fuel. If the government would implement 'biogas', but supplement it with additional pricing measures to lower its cost (e.g., by an adaptation of the excises) and demonstration campaigns to illustrate the user friendliness of the fuel, the potential rejection by the end-users might be overcome.

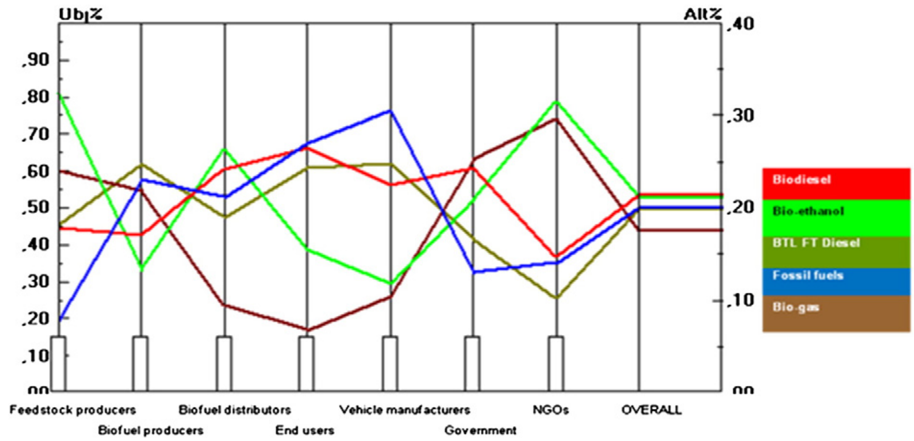

Fig. 6. Multi-actor view in AHP (biofuel example in [82].

In a second approach, the government could be faced with its preferred option(s) and the visions of the other stakeholders and decide to implement an option that offers a better consensus to all parties. For example, in the case of the Oosterweel connection (see [49]), where several 'bridge and tunnel' possibilities were evaluated, the public authority finally decided not to implement its preferred option as a result of the strong opposition of the other stakeholder groups. Instead, it chose an option that faced less barriers and was more socially acceptable. This 'consensus' process might take place through a negotiation round where all stakeholders are invited in order to reach a consensus on the decision that needs to be taken. This consensus process might also lead to the identification of new alternatives. This would lead to a feedback loop towards the beginning of the procedure, starting with new alternatives.

6. Conclusions

Transport projects are often a source of large disputes as they can generate advantages and disadvantages for various social actors. Methodologies that can incorporate these different points of view, need to be installed in order to come to sustainable solutions in the area of transport, mobility and logistics.

SMCA and MGDM are making it possible to involve the stakeholders or social actors in the decision process. Most of the applications are using a common value tree for all stakeholders.

In the MAMCA methodology, every stakeholder group has its own criteria set. In this paper, we shared the experiences on several applications of the MAMCA methodology in the transport sector. These experiences show that the MAMCA is a suitable procedure to use in the context of complex transport policy decisions. It allows the visualization of the different points of view and the structuring of the discussion. More research is needed on the weights of the stakeholders and how this could be used to influence the final outcome. Until now, we used a pragmatic approach and gave every stakeholder the same weight. Possible other approaches have to be tested. Also possible strategic bias should be analyzed more in detail. Strategic bias in the context of group decision models occurs when individuals provide preference information to a group decision model which, they perceive, will improve their own outcomes and not necessarily those of the group [33]. In the MAMCA, we should take care that within crucial steps of the methodology, such as the choice of the stakeholders, the choice of the criteria, the choice of the weights of the criteria, and the choice of the weights of the stakeholders, strategic bias is avoided. Future research should also focus on the development of a software, adapted to the MAMCA, which should lead to a better visualization of the multi-actor view.

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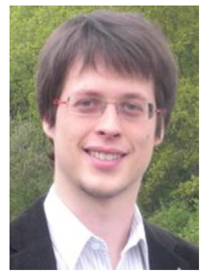

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