The Multi-Actor Multi-Criteria Analysis (MAMCA) Tool: Methodological Adaptations and Visualizations

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Abstract. In order to aid groups in complex decision-making processes, the Multi-Actor Multi-Criteria Analysis (MAMCA) methodology has been developed. The MAMCA methodology differs from the classical approaches of Multi-Criteria Decision-Analysis (MCDA) in the fact that the different actors who are involved in a project, the so-called stakeholders, are explicitly involved throughout the steps. In this research, after a brief summary of the MAMCA methodology, we will present the MAMCA software, an interactive web tool which was established based on the aforementioned methodology. In the software, several visualizations are provided to aid decision makers with analysis of the problem at hand. Furthermore, we discuss how we adapted the PROMETHEE method to provide a comprehensive overview on the performance of the different solutions to the problem, so-called alternatives. The software and the visualizations are demonstrated with an example [13], a case study for the choice of an Urban Consolidation Center (UCC) in Brussels.

Keywords: MCDA · MAMCA · PROMETHEE

1 Introduction

In order to achieve more sustainable solutions, in addition to the economical effects, the ecological, spatial and social impacts of a project should be considered [2,17,28]. The MCDA approach makes it possible to evaluate several alternatives on various quantitative and qualitative criteria [22]. A further step in the evolution of appraisal methods is the explicit introduction of the stakeholder notion in the analysis. A stakeholder is by definition any individual or group of individuals that can influence or are influenced by the decision [10].

The MAMCA methodology makes these stakeholders explicit in the appraisal methodology. MAMCA is a methodology to evaluate, amongst others, transport projects, and aid groups in complex decision-making processes. In order to include the stakeholders' opinions into the decision-making process, already in the very beginning, during the problem formulation phase, the stakeholders

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are identified together with the possible alternatives that can be considered. Thereafter, the stakeholders' criteria and priorities will be gathered. Finally, the alternatives will be evaluated on the gathered criteria. Hence, the MAMCA methodology adds an extra layer to the traditional MCDA method, namely the actor layer. In other words, per stakeholder a Multi-Criteria Analysis (MCA) model is built. All these models are aggregated in the final step.

The MAMCA methodology has already proven its effectiveness in evaluating complex sustainable mobility and transport policy decisions [20]. However, in order to create an accessible and global multi-actor multi-criteria analysis application, the MAMCA software has been developed.

The MAMCA software, follows the steps of the MAMCA methodology. First, a project is set up with a goal in mind and the alternatives are defined. Thereafter, the stakeholders are identified. Various stakeholder groups with different criteria per group can be created in the MAMCA software. While several representatives can be added to each group, the concept of participants has been introduced to the MAMCA software, to allow large groups, such as citizens, to have a direct impact on the decision by participating in a survey.

Allocating weights is possible with three methods: pairwise comparison (introduced by Saaty in [23]), equalization and manual allocation. The Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) method, developed by Brans in [3] and further extended by Brans and Vincke in [5], is provided for evaluation in the MAMCA software. Alternatively, Analytical Hierarchy Process (AHP) method, introduced by Saaty in [23] is provided as well. Moreover, diverse visualizations have been adopted to assist stakeholders in analyzing different decisions.

During the development of the software, further effort has been put into the adaption of the PROMETHEE method. In this paper, we propose an alternative series of steps to calculate the final net scores of the alternatives. The proposed steps, reach the same net scores as calculated by the original PROMETHEE method. The benefit gained by the proposed steps is that we receive a performance indicator for each alternative on all criteria, providing a comprehensive analysis on the alternatives.

In Sect. 2, some literature in the transport sector, which use MCDA methods in their appraisal are reviewed and some related software packages are discussed. The theoretical foundations of the MAMCA methodology will be reviewed in Sect. 3. Thereupon, the MAMCA software is established and introduced in Sect. 4. Herein, the focus will lie on the provided visualizations and the adaption of the PROMETHEE technique. Finally, in Sect. 5 we will discuss the future necessary steps and we will conclude in Sect. 6.

In this paper, in order to present some features of the tool and discuss the provided visualizations, we will take a case study for the choice of an Urban Consolidation Center (UCC) in Brussels from [13], as an example. In the example, the MAMCA software has been used as a methodology to consider the interest

of the stakeholders while evaluating the different implementation scenarios in the Brussels-Capital Region[1].

2 Related Work

The application of MCDA in the transport sector has a broad scope, ranging from the evaluation of policy measures in passenger transport [2], to strategic decisions [8,26], technologies [19,25], locations [15,24], and finally infrastructure projects [7]. Żak and Thiel in [28] give a comparison of several MCDA methods to solve mass transit systems' decision problems. For an overview of transport applications and applied MCDA methods see [17]. For the transport sector many different stakeholders are often involved [27,28] such as: users of the transportation, owners, managers and employees of the transportation companies, and responsible authorities for the transport operations. Not taking into account the divergent objectives of stakeholders, will make implementation of the selected alternative impractical.

PROMCALC [4] was the first published software by Mareschal and Brans, the authors of the PROMETHEE method and the GAIA visual module [6]. PROMCALC, published in 1990's, was replaced by the Decision Lab [9] developed in collaboration with the Canadian company Visual Decision in 2000s [1]. Thereafter, Visual PROMETHEE [9] has been introduced in 2010, which has spreadsheet interface, complete and partial rankings and sensitivity analysis for evaluation of PROMETHEE rankings' robustness. D-Sight Collaborative Decision-Making (CDM) [11] is a web Group Decision-Support System (GDSS) tool published in February 2010. D-Sight CDM has PROMETHEE I and II rankings, the GAIA visualization tool, sensitivity analysis and a modern user interface. Expert Choice [12] is a GDSS based on AHP, evaluating the alternatives based on pairwise comparisons. The Expert Choice software is equipped with sensitivity analysis and uses three types of comparisons namely verbal, numerical and graphical to evaluate the alternatives.

3 MAMCA Methodology

In a classical MCDA approach the following steps are taken: problem definition, developing the alternatives, developing a set of criteria and an evaluation matrix of their importance, the general evaluation of the alternatives, and finally the implementation [7,21]. Moreover, various stakeholders are often involved in the decision-making process. It is important to explicitly involve stakeholders' objectives in the process and analysis. The MAMCA methodology differs from the classical approach of MCDA in the explicit introduction of stakeholders in a very early stage. These stakeholders will be key to identify and evaluate the criteria, which are here equal to the objectives of the stakeholders.

[1] Understanding of the example is not necessary in this article. It is uniquely used to present the software.

The first step in the MAMCA approach is the definition of the problem and the identification of the possible alternatives submitted for evaluation. The stakeholders are identified in the second step. Stakeholders are people who have an interest 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 who need to be consulted and whose views should be taken into account in the evaluation process.

The choice and definition of the evaluation criteria are primarily based on the identified stakeholder objectives and the purposes of the alternatives considered. 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 multi-criteria analysis. The given weights represent the importance the stakeholders attach to these objectives.

In the fourth step, for each criterion, one or more indicators are constructed: direct quantitative indicators such as money spent, number of lives saved, reductions in CO2 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. The measurement method for each indicator is also made explicit; for instance for the "economic activity" criterion, the number of jobs created counted by the number of people is considered. This allows measuring of the performance of each alternative 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 an evaluation matrix, aggregating each alternative's contribution to the objectives of all stakeholders. Any MCDA-method can be used to assess the different strategic alternatives. The PROMETHEE method has, for example, been extended in [18], the Analytical hierarchy process (AHP) method in [23] and ELECTRE in [14]. These methods give each stakeholder group the liberty of having their own criteria, weights and preference structure and only at the end of the analysis the different points of view are confronted.

The multi-criteria analysis developed in the previous step eventually (in step six) leads to a classification of the proposed alternatives revealing the strengths and weaknesses of the proposed alternatives. A sensitivity analysis is performed in this stage in order to assess the stability of this ranking. More important than the ranking, the multi-criteria analysis reveals the critical stakeholders and their criteria. The multi-actor, multi-criteria analysis provides a comparison of different strategic alternatives, and supports the decision makers in making their 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.

The last stage of the methodology (step 7) includes the actual implementation. When the decision is made, steps have to be taken to implement the chosen

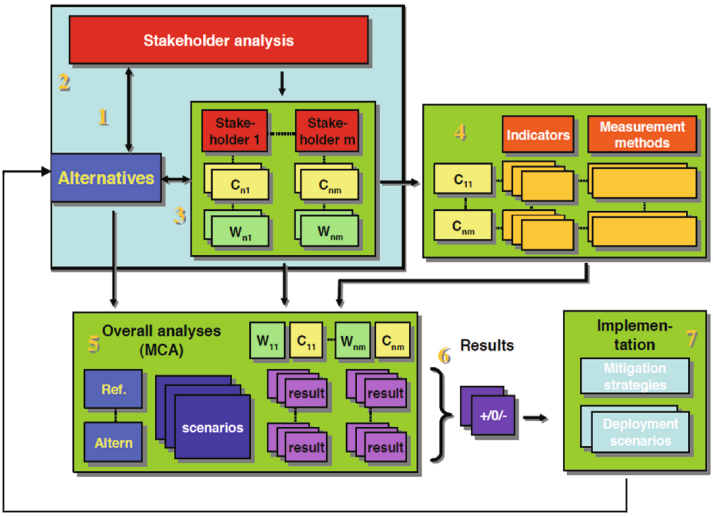

Fig. 1. Methodology for the multi-actor multi-criteria analysis (MAMCA) [16]

alternative by creating deployment schemes. The information on the points of view of each stakeholder, received from the previous steps, tremendously helps to define the implementation paths. The overall methodology of the MAMCA is shown in Fig. 1.

4 MAMCA Software

The MAMCA software is developed in Java and PHP and runs inside the GlassFish and Apache application containers, respectively. It contains three layers: the first layer is the data access layer, the second layer is the logic layer, programmed in Java, and the user interface is the third layer.

Fig. 2. MAMCA software

Figure 2 demonstrates a screen-shot of the MAMCA software. It displays the first page of the workspace after a project manager has logged in to the software and has selected a project. We can see the project title and the evaluation type (PROMETHEE or AHP). Afterwards, we can see the navigation bar which follows the steps defined in the MAMCA methodology.

The MAMCA tool can be accessed after logging in to the platform by a user-name and password. Thereafter, either a new project should be created or we can access an existing project. When creating a new project, the title, goal, description and evaluation type of the project should be identified.

4.1 Alternatives

In the first step, demonstrated in Fig. 2, we can define new alternatives, modify or remove them. The alternatives can be added one by one or imported from a Microsoft Excel sheet. The alternatives list can be exported as a Microsoft Excel sheet. In the presented project to implement an urban consolidation center in Brussels, six alternatives have been defined. Each alternative has a name and description, which is shown if the pointer stays on the alternative name in the table.

4.2 Stakeholder Analysis

In the second step, involved stakeholders are introduced. Four types of actors are introduced in the MAMCA tool: project manager, actors, participants and experts. Project managers are the creators of a project. They will define the project and the alternatives, which are the same for all the stakeholders. Thereafter, the project manager will introduce the involved stakeholders as groups of actors, participants or experts and will invite one or many people to each group.

Actors are stakeholder groups that are engaged in the project and are interested in the outcome of the project. Thus, apart from their defined task they will have access to the result of the project. Each actor group has different privileges. When creating the actor groups, it has to be defined: (a) if the actors in each group will add their own criteria or if they are pre-defined and added by the project manager, (b) if the evaluation table will be filled in by the actors or if it will be filled in by the project manager or experts.

In the MAMCA process, often the representatives of the identified stakeholder groups are invited. In order to find more equitable and sustainable solutions, it is necessary to involve all stakeholders, and not only their representatives, especially for large groups, such as citizens. The increasing digitalization of the world and the knowledge-based society ensure that people will increasingly be able to participate in the decision process. Even stronger, people will ask to be involved in these processes. In order to explicitly integrate a broad set of various and often conflicting points of view, the concept of participants has been introduced in the MAMCA software. Participants are people from large groups such as citizens, which are important to consider but are hard to contact in person. In order to include more stakeholders' opinions, the process has been made

brief, and the participant groups receive a link to fill in a pairwise comparison based on their priorities.

Furthermore, experts have been introduced to the MAMCA methodology to assist on the fourth step of MAMCA methodology, where indicators and measurement methods to evaluate alternatives are defined. For each stakeholder group introduced in the second step, we can define whether the stakeholder group has the expertise to fill in the evaluation table or if an expert will be invited to carry out the evaluation. Similar to the alternatives list, the actor groups list can be imported and exported. Figure 3 shows the actors for the UCC case project.

Group Name	Group Type	Criteria Definition	Evaluations Input	Parameter Lock	Action
Receivers	Actor	Project Manager	Project Manager	No	
Shippers	Actor	Actor	Project Manager	No	
LSP	Actor	Actor	Expert	No	
Citizens	Actor	Project Manager	Expert	No	
Authorities	Actor	Actor	Actor	No	
Citizens_Survey					
Citizens_Expert					
LSP_Expert					

Fig. 3. MAMCA software: stakeholder groups

4.3 Criteria and Weights

In the third step, per stakeholder group the criteria are defined. Each criterion has a name, group and description. It is important to realize that the criteria are different for each stakeholder group. The criteria are added by actors during the project or are predefined by the project manager. The criteria can be imported and exported as an Microsoft Excel sheet.

The fourth step is the weight allocation. In this step, three methods are provided to allocate a weight to each criterion. If we equalize the weights, the criteria groups will each get an equal weight, thereafter those weights will be equally divided to the criteria in that group. We can assign the weight manually. If the weights do not sum up to 1, a ratio of the weights will be saved. Finally, the pairwise comparison method introduced by [23] can be used to weigh the criteria.

4.4 Evaluation

The fifth step is the evaluation step. When creating the project, we must choose between AHP and PROMETHEE. If the chosen method is AHP, alternatives will be compared pairwise for each criterion. Please refer to [23] for further explanation on the AHP technique. If PROMETHEE is the chosen appraisal method, the evaluation table has to be filled in, indicating on a quantitative or qualitative scale how each alternative has scored on each criterion. The parameters for each criterion have to be defined as well. In the following, we will further discuss the PROMETHEE technique.

PROMETHEE Technique. PROMETHEE is an outranking method to rank a finite set of alternatives based on a set of often conflicting criteria. PROMETHEE I and PROMETHEE II has been originally introduced by Brans in [3]. Thereafter, several other versions of PROMETHEE have been introduced, which we will not review in this paper as they are not relevant to our research.

The basic principle of PROMETHEE II is based on the pairwise comparison of alternatives along each recognized criterion. In PROMETHEE II, each alternative is evaluated on different criteria, providing the evaluation table. In order to get the ranking of the alternatives, in addition to the evaluation table, three sets of information are required: the weight allocated to each criterion, the preference function for each criterion and whether the criterion is to be maximized or minimized. Brans and Vincke suppose that all the criteria have the same importance or the stakeholders will introduce normalized weights as their preference index [5]. The preference function takes the difference between the evaluations of each two alternatives, and gives a preference degree ranging from zero to one. Brans and Vincke in [5] proposed six basic types of preference function: usual criterion, U-shape criterion, V-shape criterion, level criterion, V-shape with indifference criterion and Gaussian criterion. Furthermore, for each criterion, the value of an indifference threshold: q, and the value of a preference threshold: p, and the value of an intermediate value between p and q, s has to be defined. The stepwise procedure for calculating the ranking of alternatives has been discussed in [3], and demonstrated, as in Fig. 4 by Behzadian et al. in [1].

4.5 Results

The sixth step which is the multi-actor tab, includes the visualizations and analysis which will be discussed in details in the following.

Multi-Actor Analysis. In Fig. 5 the scores of the alternatives derived from all stakeholder groups are aggregated in one chart providing the multi-actor view. The scores of alternatives for each group is an arithmetic mean of the alternatives' scores for each stakeholder in that group. As Fig. 5 reveals, there is not always a single best alternative available. On the other hand, we can realize Scenario 2b and 3b have performed better compared to the other alternatives. Scenario 2b has scored positive for all the stakeholder groups except for the Citizens. It has been the best alternative for the Shippers and LSP. Furthermore, it has scored positive for the Receivers and Authorities. It has to be investigated how to adapt Scenario 2b to better perform for the Citizens. Scenario 3b has been the best alternative for Citizens and Authorities, and has received positive scores for the LSP and Receivers. Further analysis can be applied to become aware of how to adjust Scenario 3b to better perform for the Shippers.

Multi-Actor Box Chart Analysis. Figure 6 provides a comprehensive overview on the alternatives' scores. It demonstrates the range of the scores each alternative has received and where the scores are more concentrated, while

Step 1. Determination of deviations based on pair-wise comparisons

$$d_j(a,b) = g_j(a) - g_j(b) \qquad (1)$$

Where $d_j(a,b)$ denotes the difference between the evaluations of a and b on each criterion.

Step 2: Application of the preference function

$$P_j(a,b) = F_j[d_j(a,b)] \qquad j=1,\ldots,k \qquad (2)$$

Where $P_j(a,b)$ denotes the preference of alternative a with regard to alternative b on each criterion, as a function of $d_j(a,b)$.

Step 3: Calculation of an overall or global preference index

$$\forall a,b \in A, \qquad \pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j \qquad (3)$$

Where $\pi(a,b)$ of a over b (from 0 to 1) is defined as the weighted sum $p(a,b)$ of for each criterion, and w_j is the weight associated with jth criterion.

Step 4: Calculation of outranking flows/ The PROMETHEE I partial ranking

$$\phi^+(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a,x) \qquad (4) \qquad \text{and} \qquad \phi^-(a) = \frac{1}{n-1} \sum_{x \in A} \pi(x,a) \qquad (5)$$

Where $\phi^+(a)$ and $\phi^-(a)$ denote the positive outranking flow and negative outranking flow for each alternative, respectively.

Step 5: Calculation of net outranking flow/ The PROMETHEE II complete ranking

$$\phi(a) = \phi^+(a) - \phi^-(a) \qquad (6)$$

Where $\phi(a)$ denotes the net outranking flow for each alternative.

Fig. 4. Stepwise procedure of PROMETHEE II [1]

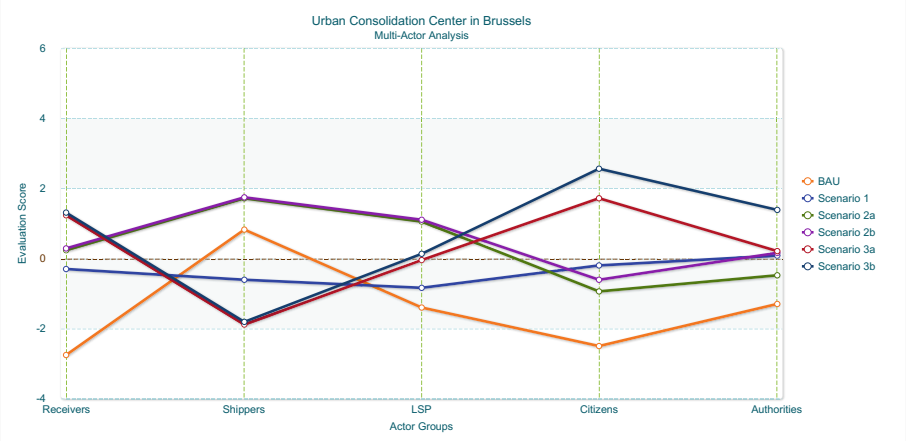

Fig. 5. MAMCA software: multi-actor analysis

not directly showing each stakeholder's opinion. This visualization is especially beneficial when we have a large number of stakeholders and stakeholder groups. The top and bottom quartiles of the alternative's scores are demonstrated by the lines, and the green and blue boxes show the middle top an middle bottom

quartiles respectively. Scenario 1 has a high concentration in the negative scores, representing that it has received negative scores from all the stakeholders. Scenario 2b has a rather high concentration in the positive scores, showing that it has received positive scores from most of the stakeholders. While Scenario 3b has a very high top score, the opinion of stakeholders has not been united about it, as the box has a large area.

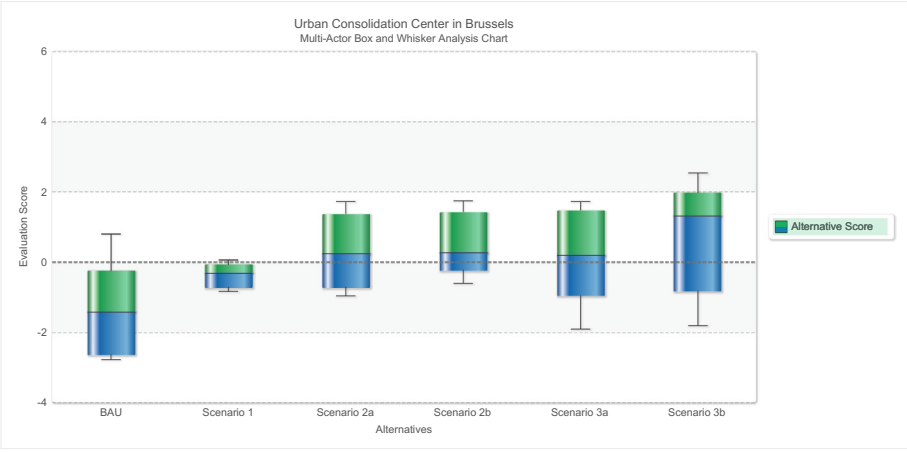

Fig. 6. MAMCA software: multi-actor box chart analysis

Alternatives Evaluation Analysis. In order to calculate alternatives' net scores with PROMETHEE II, a five-step procedure has been introduced by [3], demonstrated in Fig. 4 by Behzadian et al. [1]. In this research, we propose a four-step procedure to calculate the alternatives' net scores, presented in Fig. 7. In the proposed procedure, the first two steps are identical to the original steps.

The benefit of using the proposed procedure is that we evaluate the performance of each alternative on all criteria. In the third step of the procedure, a matrix, shown in Fig. 8, is built representing the performance of alternatives on the criteria set. Thereafter, in step four, the net score of each alternative is calculated summing up their performance on the criteria set, multiplied by the criteria weight. It is important to mention that the final net scores of alternatives calculated by the proposed four-step procedure are the same as the net scores calculated by the original five-step procedure.

Figures 9 and 10 exhibit results of the calculation based on the four-step procedure suggested in Fig. 7. In these figures, we can see how alternatives have performed over the criteria set of each stakeholder group. Figure 9 is from analysis of the Citizens. Scenario 2b has scored positive for all the stakeholder groups except Citizens. Thus, in Fig. 9 we can investigate how we can adapt this alternative in order to perform better for Citizens. While Scenario 2b has scored negative on almost all the criteria of this group, we assume if the noise problem would be addressed, the score of the alternative will change greatly.

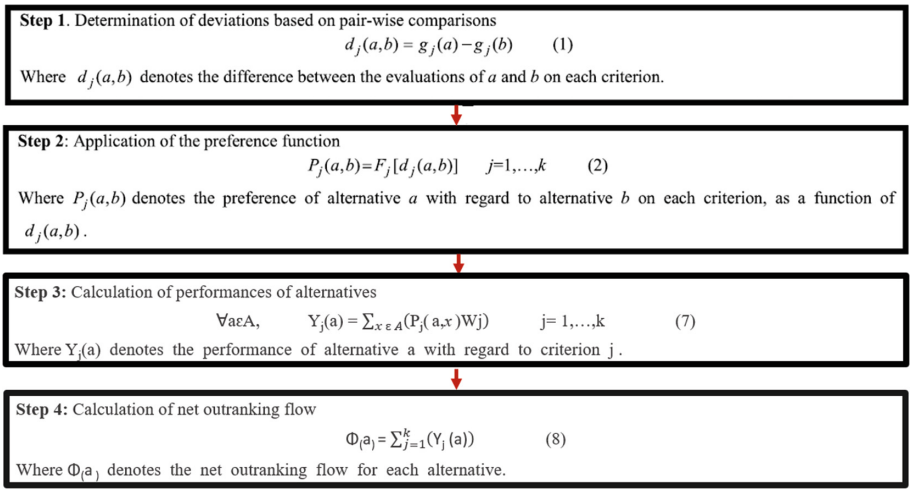

Fig. 7. Stepwise procedure of adapted PROMETHEE calculation (Step 1 and 2 from [1], Step 3 and 4 from own setup)

This hypothesis will be tested using sensitivity analysis in the following. Furthermore, in Fig. 10, we observe that the reason for scenario 3b receiving a negative score for the Shippers, while receiving a positive score for all the other stakeholder groups, is due to the high transport cost of this scenario. Thus, a solution such as a subsidy from the government, in order to lower the cost of this scenario for the Shippers, can provide an alternative that is satisfying to all stakeholders.

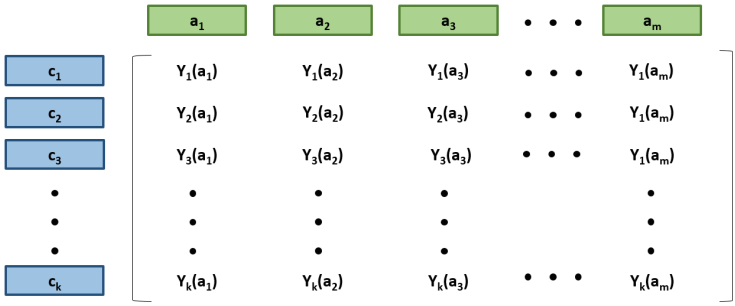

Fig. 8. The matrix representing the performance of alternatives on the criteria (own setup)

Sensitivity Analysis. In the MAMCA software, we provide two sensitivity analysis: weight analysis and evaluation analysis. In the weight analysis, using a flowing bar chart, criteria weights of different stakeholder groups can be changed

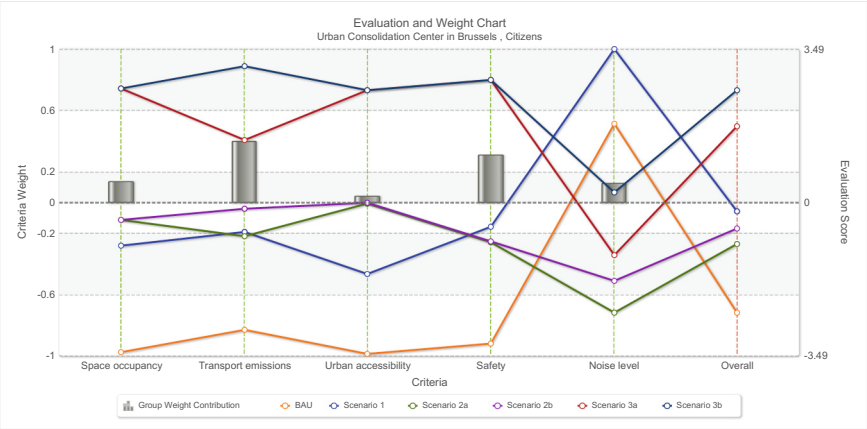

Fig. 9. MAMCA software: citizen's alternatives evaluation analysis

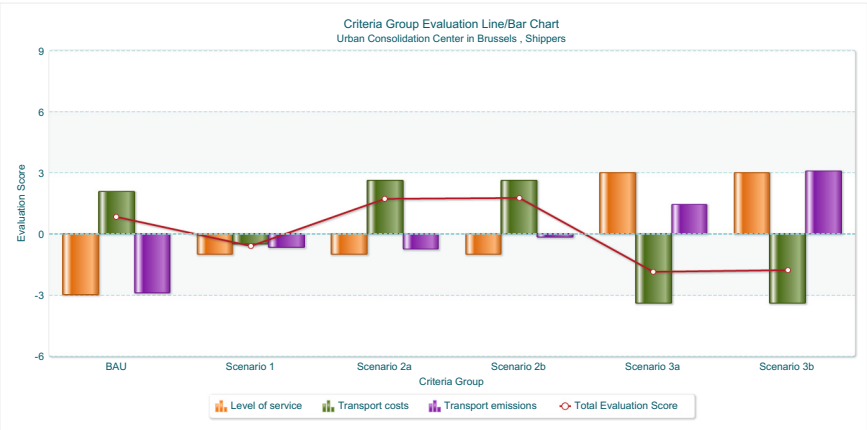

Fig. 10. MAMCA software: shipper's alternatives evaluation analysis

and the result of these changes are demonstrated in the multi-actor analysis chart. Hence, we can investigate how changing the weights of some of the criteria for one or more of the groups will affect the results in the multi-actor view. In the second case, evaluation analysis, we can adjust the "Alternatives Evaluation Analysis" chart of some of the stakeholder groups, and the result of this will be shown in the "Multi-Actor Analysis" chart. Changing the noise level of Scenario 2b for Citizens results in receiving slightly positive score for this scenario. Thus, we realize if the noise problem of the Scenario 2b will be solved, this scenario will have positive scores from all the stakeholders.

5 Discussion and Future Work

The use of the MAMCA software has made interactive workshops possible. In these interactive workshops, the focus is on the discussion, as well as on the weights of the criteria and the evaluation. Directly a common understanding of the problem and better insight is gained about the objectives and concerns of the other stakeholders. Finally, some template and guided projects, such as the city distribution game with 5 stakeholder groups, namely the shippers, the logistic service providers, the receivers, the citizens and the authorities can be used for training and exercise purposes.

A future work in the MAMCA development is to incorporate the "participation" concepts, by further enhancing the implemented "Participant" concept. The nature of the problem could be defined by stakeholders, others than the public officials and organized interests. Participation addresses the need for a dynamic approach facilitating mutual decision making accessible by a wider community. Herewith decision making goes beyond the existing political structures and dialogs.

Additional future work in the MAMCA software is integrating co-creation and co-design into the planning and decision-making process. Identification of alternatives with high levels of cooperation requires an interface facilitating identification and integration of the co-created alternatives into the evaluation process. Co-creation incorporates the formal structures of planning and evaluation, with the generally more informal process of identifying the alternatives.

6 Conclusion

In this paper, the MAMCA software was introduced, in order to aid groups in decision-making process and provide support to all the stakeholders. Software follows the steps of the MAMCA methodology, involving stakeholders explicitly in the appraisal process. Using the MAMCA software in interactive workshops, further enhances a mutual understanding between the stakeholders.

The softwares introduced in the related work section have either AHP or PROMETHEE for evaluation. The MAMCA software provides a choice of both of the algorithms. In the reviewed softwares, several stakeholder groups can be involved, but the criteria are the same for all the groups. In the MAMCA software, each stakeholder group has their own criteria. A MCA model is built for each stakeholder and aggregated in the final step. The "participant" concept to include large groups' opinions in the decision-making process, through a survey, has been introduced in this paper.

In this contribution, a four-step procedure has been proposed as an alternative to the original five-step PROMETHEE algorithm. The proposed four-step procedure provides the same net scores for the alternatives as the original PROMETHEE. The benefit of the proposed procedure is the performance indicators received for each of the alternatives on the criteria set. Several visualizations such as "Alternatives Evaluation Analysis" providing an overview on

performance of the alternative on the criteria set with positive and negative scores, "Multi-Actor Analysis" and "Multi-Actor Box Chart Analysis" are further contributions of this paper.

References

1. Behzadian, M., Kazemzadeh, R.B., Albadvi, A., Aghdasi, M.: PROMETHEE: a comprehensive literature review on methodologies and applications. Eur. J. Oper. Res. **200**(1), 198–215 (2010)
2. Bouwman, M.E., Moll, H.C.: Environmental analyses of land transportation systems in The Netherlands. Transp. Res. Part D: Transp. Environ. **7**(5), 331–345 (2002)
3. Brans, J.P.: L'ingenierie de la Decision, l'Laboration d'Instruments d'Aidea la Decision. Universite Laval, Colloque sur l'Aidea la Decision. Faculte des Sciences de l'Administration (1982)
4. Brans, J.P., Mareschal, B.: The PROMCALC & GAIA decision support system for multi-criteria decision aid. Decis. Support Syst. **12**(4–5), 297–310 (1994)
5. Brans, J.P., Vincke, P.: Note-A preference ranking organisation method: (The PROMETHEE method for multiple criteria decision-making). Manage. Sci. **31**(6), 647–656 (1985)
6. Brans, J.P., Vincke, P., Mareschal, B.: How to select and how to rank projects: the PROMETHEE method. Eur. J. Oper. Res. **24**(2), 228–238 (1986)
7. De Brucker, K.: Sociaal-Economische Evaluatie van Overheidsinvesteringen in Transportinfrastructuur: Kritische Analyse van het Bestaande Instrumentarium Ontwikkeling van een Eclectisch Evaluatie-Instrument. Garant, Leuven (1998)
8. Dooms, M., Verbeke, A., Macharis, C., SJegers, R.: De Zaak DHL. Het Regional Hub Project van DHL in Brussel-Nationaal: Een Socio-Economische en Maatschappelijke Evaluatie. Garant, Leuven (2006)
9. Geldermann, J., Zhang, K.: Software review: "Decision Lab 2000". J. Multi Criteria Decis. Anal. **10**(6), 317 (2001)
10. Hannan, M.T., Freeman, J.: Structural inertia and organizational change. Am. Sociol. Rev. **49**, 149–164 (1984)
11. Hayez, Q., De Smet, Y., Bonney, J.: D-Sight: a new decision making software to address multi-criteria problems. Int. J. Decis. Support Syst. Technol. (IJDSST) **4**(4), 1–23 (2012)
12. Ishizaka, A., Labib, A.: Analytic hierarchy process and expert choice: benefits and limitations. OR Insight **22**(4), 201–220 (2009)
13. Lebeau, P.: Towards the Electrification of City Logistics. Vrije Universiteit Brussel, Brussel (2016)
14. Leyva-Lopez, J.C., Fernandez-Gonzalez, E.: A new method for group decision support based on ELECTRE III methodology. Eur. J. Oper. Res. **148**(1), 14–27 (2003)
15. Macharis, C.: Strategic modeling for intermodal terminals: socio-economic evaluation of the location of barge/road terminals in flanders. Vrije Universiteit Brussel (2000)
16. Macharis, C.: The importance of stakeholder analysis in freight transport: the MAMCA methodology. Eur. Transp. (Transporti Europei) **25**(26), 114–126 (2004)
17. Macharis, C., Ampe, J.: The Use of Multi-Criteria Decision Analysis (MCDA) for the Evaluation of Transport Projects: A Review. Euro XXII Prague Book of Abstracts (2007)

18. Macharis, C., Brans, J.-P., Mareschal, B.: The GDSS promethee procedure. J. Decis. Syst. **7**(4), 283–307 (1998)
19. Macharis, C., Springael, J., De Brucker, K., Verbeke, A.: PROMETHEE and AHP: the design of operational synergies in multi-criteria analysis.: strengthening PROMETHEE with ideas of AHP. Eur. J. Oper. Res. **153**(2), 307–317 (2004)
20. Macharis, C., Turcksin, L., Lebeau, K.: Multi-Actor Multi-Criteria Analysis (MAMCA) as a tool to support sustainable decisions: state of use. Decis. Support Syst. **54**(1), 610–620 (2012)
21. Nijkamp, P., Van den Bergh, C.J.M., Soeteman, F.J.: Regional sustainable development and natural resource use. World Bank Econ. Rev. **4**(1), 153–188 (1990)
22. Pugnaire, P.V.: Multicriteria Decision-Aid (1992)
23. Saaty, T.L.: Group decision making and the AHP. In: Golden, B.L., Wasil, E.A., Harker, P.T. (eds.) The Analytic Hierarchy Process, pp. 59–67. Springer, Heidelberg (1989)
24. Sirikijpanichkul, A., Ferreira, L.: Multi-objective evaluation of intermodal freight terminal location decisions (2005)
25. Tzeng, G.H., Lin, C.W., Opricovic, S.: Multi-criteria analysis of alternative-fuel buses for public transportation. Energ. Policy **33**(11), 1373–1383 (2005)
26. Vreeker, R., Nijkamp, P., Ter Welle, C.: A multi-criteria decision support methodology for evaluating airport expansion plans. Transp. Res. Part D: Transp. Environ. **7**(1), 27–47 (2002)
27. Żak, J.: The MCDA methodology applied to solve complex transportation decision problems. In: 13th Mini-EURO Conference (2002)
28. Żak, J., Thiel, T.: Multiple criteria evaluation of the development scenarios of the mass transit system. In: Selected Proceedings of the 9th World Conference on Transport Research (2001)