The Multi-Actor Multi-Criteria Analysis (MAMCA) for Mass-Participation Decision Making

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Abstract. The Multi-Actor Multi-Criteria Analysis is a methodology that allows for the involvement of multiple stakeholders within a decision-making process. It reveals the consensus and conflicts between the different groups of people that are involved in the evaluation but hold different interests. Nowadays, the concept of the "stakeholder" in MAMCA gradually shifts to the "stakeholder group", and there is a need for involving more than one evaluator in the stakeholder group to make sure all the voices from the group will be heard instead of being represented by one. Especially when a stakeholder group contains a large variation in interests, concerns and socio-economic characteristics. Additionally, one group can have subgroups that might be hard to reach, and therefore are not or un-der-represented in the analysis. This is typically the case for the 'citizens' stakeholder group.

In order to fulfill the needs of the involvement of many different stakeholders within stakeholder groups, the mass-participation function was developed in MAMCA and the MAMCA survey tool is designed. This tool allows the decision-maker to design the dedicated survey for the stakeholder group which needs the mass-participation function. The easy-to-understand evaluation process is used to avoid time-consuming elicitation. It is possible to check the homogeneity and heterogeneity of the stakeholders within the stakeholder group based on the socio-economic profiles collected in the survey.

Keywords: Mass participation · Multi-criteria decision making · Multi actor multi criteria analysis · Survey

1 Introduction

In the decision-making process of public management, stakeholder involvement plays an important role. The stakeholders, as individuals, have influences on the decision-making [1]. Normally they have different backgrounds, representing different organizations/groups. They have interests in the objectives of the project and will be affected by the consequence of the decision taken [2]. By involving the stakeholders, the decision-maker can have a better understanding of the objectives of the different parties, which typically leads to higher implementation acceptance and lower chances of project failure [3]. In the meantime, the stakeholders are able to voice their own interests or concerns.

Furthermore, the stakeholders can be aware of the presence of other stakeholders, and the process of the evaluation can reflect their mutual interests and conflicts explicitly [4].

Multi-Actor Multi-Criteria Analysis (MAMCA) is a methodology that extends the traditional Multi-Criteria Decision-Making (MCDM) methods by allowing the inclusion of multiple stakeholders (see Fig. 1). The involvement of stakeholders in MAMCA facilitates a more rational solution in the field of energy [5], transportation [6], logistic and mobility [7].
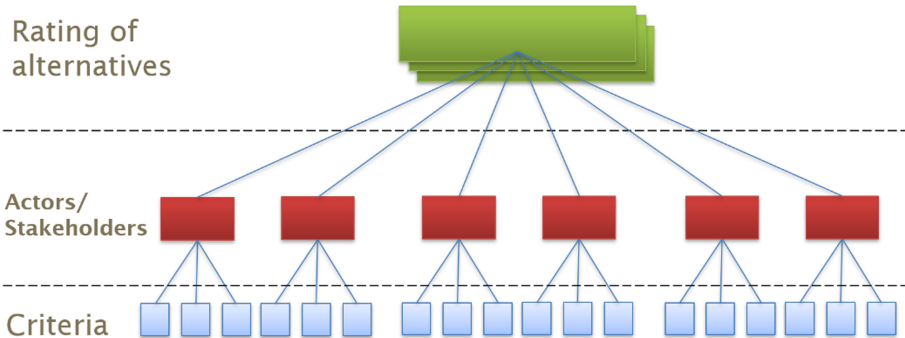

Fig. 1. MAMCA structure

In the MAMCA evaluation process, it is found that some stakeholder groups are not suitable to be represented by one or a few stakeholders. Because even when they have the same criteria, their priority to these criteria can be different [8]. Thus, a need for mass-participation comes to the table of discussion. An extended survey tool designed for mass-participation involvement in MAMCA software is developed.

In this paper, we will first explain the further developed MAMCA methodology towards a mass-participation tool. Then, the MAMCA survey tool is introduced. Finally, a didactic case study of supply chain management is applied to demonstrate the mass-participation function.

2   MAMCA Methodology Evolution

The MAMCA methodology was proposed to reach a consensus among all the stake-holders. In Fig. 2, the 7 steps of the MAMCA methodology is shown: (1) alternatives definition, (2) stakeholder analysis, (3) criteria and weights definition, (4) criteria indicators and measurement methods definition, (5) overall analysis and ranking, (6) results and (7) implementation. It is clear to see, after defining the alternatives, the stakeholder analysis is taken. Stakeholders are identified in the early stage [9]. Each stakeholder takes individual Multi-Criteria Analysis (MCA) based on his/her own criteria tree [10]. The stakeholders can evaluate the alternatives with their own preferences based on the priorities of their criteria set. They do not confront the conflicts from other stakeholders. Only at the end of the evaluation, they can check the result of their evaluation, as well as others'. In such a way, there will not be an intervention among the assessment of different

stakeholders. And during the result analysis, they will be aware of the presence of other common or conflicting interests or concerns from other stakeholder groups. During the discussion of the result, the stakeholders can express their interests and explain the result of the evaluation. The decision-maker will find a win-win solution for all stakeholders easier after the discussion.
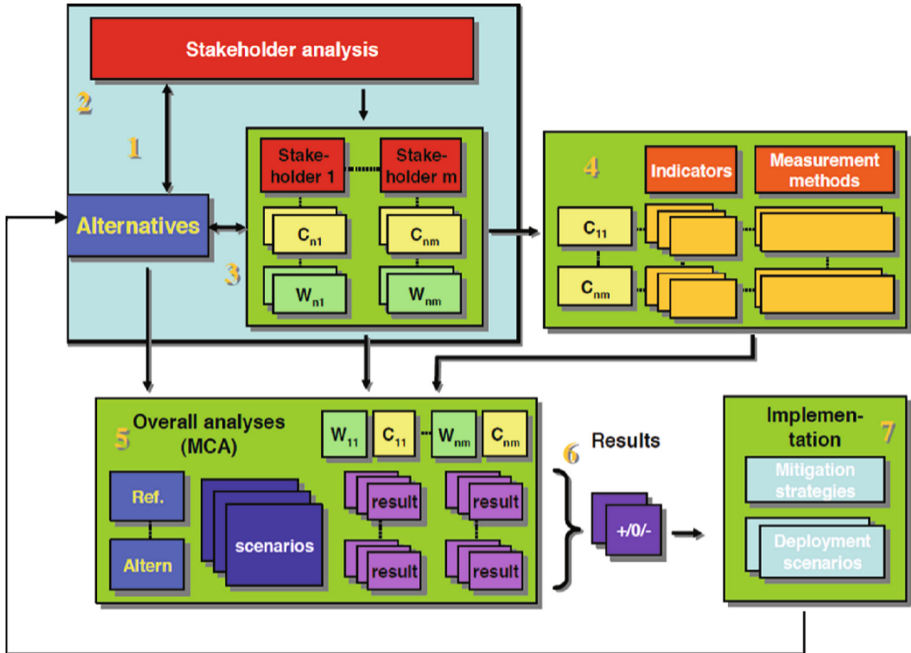

Fig. 2. MAMCA methodology [11]

After the methodology was introduced for years [12], it was found that normally there is a need for more than one stakeholder to represent their interest party. More stakeholders are invited in the workshop for the evaluation. Turcksin et al. invited 31 highly representative stakeholders from 7 different groups to assess several biofuel options for Belgium that can contribute to the binding target of 10% renewable fuels in transport by 2020 [13]. Sun et al. surveyed 48 highly representative stakeholders from 8 groups to evaluates the low-carbon transport policies in Tianjin, China [14]. Keseru et al. invited 40 participants into 7 different groups to improve mobility in the city center of Leuven, Belgium [15]. It could be foreseen that the MAMCA evaluation is not satisfied with only one representative for each group, that is, the concept of the "stakeholder" move to "stakeholder group", as it is hard for only one stakeholder to represent the whole interest and preference of his/her group. Multiple stakeholders can be invited for the evaluation of their stakeholder group. Stakeholders within one group already negotiate, but there is still a bit of struggle with loud and quiet people. They may share the same criteria, yet they can hold different priorities to the criteria (see Fig. 3).
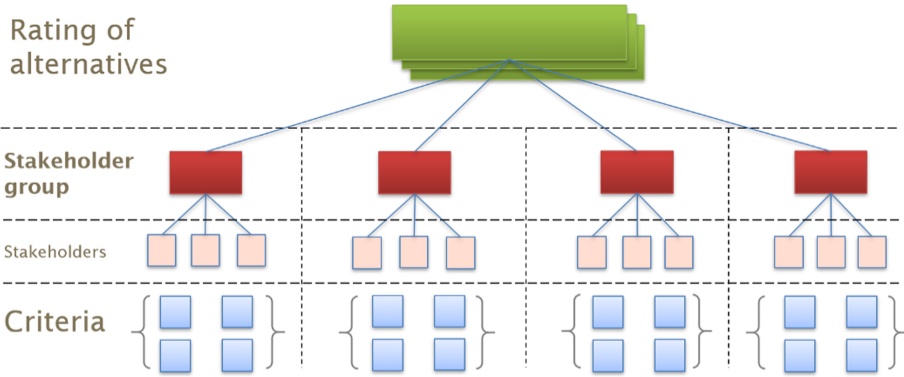
Fig. 3. Evolved MAMCA structure

To better adapt the concept of stakeholder group involvement, and to better facil-itate the workshop, a new MAMCA software was developed [16]. The new software enhances the participation experience, which can better include the evaluation of multi-ple stakeholders in one stakeholder group. The standard MAMCA participation system was introduced in the software (see Fig. 4). The decision-maker can identify the alterna-tives and define the criteria with stakeholders in the workshop. And the decision-maker can coordinate the evaluation of the stakeholders. The weight allocation on criteria of the stakeholder group is the arithmetic mean of all the ranking scores of the stakeholders in the group, and the box plot of the weights' differences will be shown. This participation system can help stakeholders understand the impact on each other. They can check the points of view not only between the stakeholder groups but also within the group.
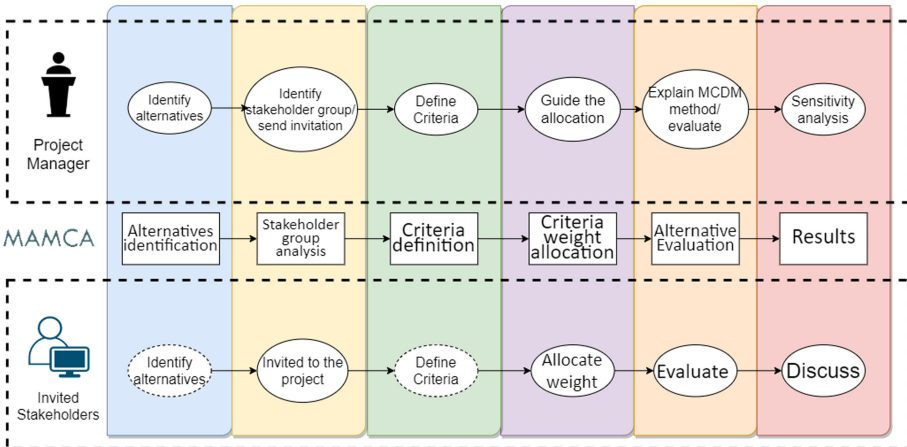

Fig. 4. The MAMCA participation system [16]

Still, for some stakeholder groups, this participation system is not well suited. Espe-cially when there are stakeholder groups like citizens. This kind of group could have a

massive amount of stakeholders, it is important to collect more profiles from the group [17]. The opinions from the group need to be heard as much as possible, as it is considered a way to reduce uncertainty and to improve the democratic legitimacy of those processes. Because the stakeholders in the group normally have different Socioeconomic status (SES), the different voices need to be heard, instead of only represented by one or limited amount during the evaluation. On the other hand, such stakeholders are hard to reach. Seeing it is always time-consuming and costly to assemble a large number of stakeholders at the same time, it is not feasible to invite all the stakeholders in the workshop for the evaluation [18]. A new evaluation model for better assessment by such stakeholder groups is needed. Thus, mass-participation decision making is proposed.

3　Mass-Participation Decision-Making in MAMCA

Mass-participation is sought targeting to certain stakeholder group, which contains the following attributes:

- A massive number of stakeholders within one stakeholder group;
- The group that requires more than one representative to voice the preferences of the group;
- The stakeholders in the group have various relevant socioeconomic status;
- The stakeholders are hard to reach and assemble;
- The stakeholders need an easy to understand and less time-consuming evaluation method.

Survey data collection is suitable for the evaluation in such a stakeholder group that fulfills the needs of the mentioned attributes [19]: Because it is not possible to gather all stakeholders in a single MAMCA workshop, the survey offers them the possibility to do the weight allocation and evaluation individually, at a non-specified time. The survey consists of the following elements: Designing and answering survey questions, weight allocation, and alternative evaluation. In the survey, the decision-maker can also ask questions on their socio-economic profiles for later research. The Profile Ranking with Order Statistics Evaluations (PROSE) is applied for the evaluation [20]. This approach combines MCDA, voting theory. After the evaluation, the decision-maker can import the survey data to the MAMCA model of the main project. It is also possible to do a post-hoc analysis to find out the homogeneity and heterogeneity within the stakeholder group. As shown in Fig. 5, the MAMCA survey model aimed for mass-participation decision-making is proposed. In such a way, the stakeholders and the decision-maker can work independently. The stakeholders can weigh the criteria and evaluate the alternatives under the assistance of the survey tool instruction, without guidance from the decision-maker, unlike the standard MAMCA participation system where the stakeholders have to participate in the physical or online workshop. In the following sub-section, the necessary steps of the model are clarified.

3.1　Designing and Answering Survey Questions

When there is a massive amount of stakeholders in one stakeholder group, instead of treating the stakeholder group as a whole all the time, there is a need to look inside
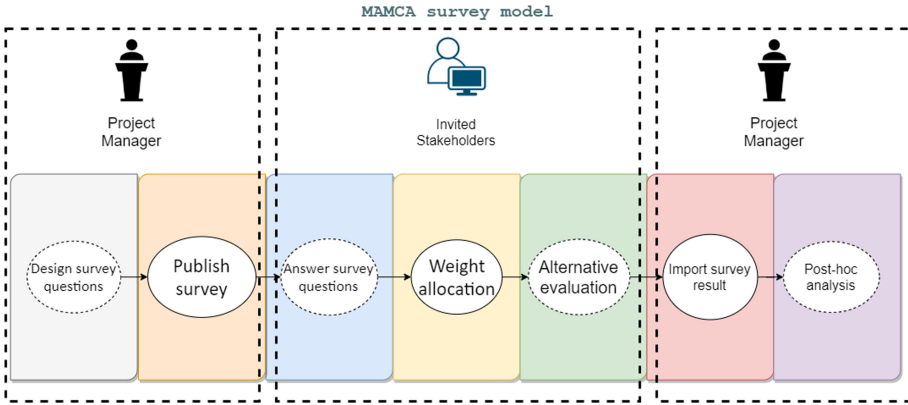
Fig. 5. MAMCA survey model

the characteristics of individuals. In a stakeholder group like citizens, the priorities and preferences of stakeholders can vary according to gender, age, income, education, etc. [21]. By collecting socio-economic profiles of the stakeholders it can provide a "bird eye view" of the stakeholder group, which helps the decision-maker identify profiles, concerns, and opinions. It displays combined and comparable statistical snapshots of the stakeholder group.

The SES are important indicators in mass-participation decision-making, as the stakeholder group like "citizens", "residents" is in a more general term, that it is possible to find a significant difference statistically of the criteria priority ranking or alternative evaluation. In that case, the stakeholders can be regrouped or divided into sub-groups [22].

The analysis of the stakeholder group's homogeneity and heterogeneity can be done by asking about some specific stakeholders' SES. The decision-maker can design survey questions for inquiring. After collecting the socio-economic profiles of the stakeholders, it is possible to do a post-hoc analysis by combining the criteria priority ranking and socio-economic profiles.

3.2 Weight Allocation and Alternative Evaluation

The key point of the evaluation is to be fast, easy to understand but also mathematically sound. Because of the characteristics of the mass-participation stakeholder group, stakeholders are often hard to reach, and they do not take the time to understand the methodology of the calculation, but focus on expressing their preference and priority. Also, non-technical stakeholders are difficult to understand the mathematical meaning of the evaluation methods [23]. Thus, PROSE is chosen. This method applies a weighted sum approach based on order statistics to combine the individual profile distribution. It is well suitable for mass-participation evaluation, as it does not considers only the mean distribution values, but also standard deviations [20].

Weight Allocation. An efficient and transparent weight elicitation technique proposed by Kunsch and Brans is applied in this model, which is based on semantic relative-importance classes; stakeholders are required to weigh the criteria based on their priorities [24]. They need to represent relative importance's on an ordinal score level: 1 (Least important), 2 (Less important), 3 (Middle), 4 (More Important), 5 (Most important). The scale is chosen based on the magic number 7 plus or minus 2; by choosing the 5-point Likert scale (LS), the stakeholders can have space of the mind to process the information [25]. In the meantime, the priority ranking has enough levels concerning the accuracy of the weighing. Plus, the "0" class (Not relative) is added for giving a vanishing weight in the judgment. Stakeholders are asked to define relative-importance classes in the above-mentioned scale. They need to rank at least one criterion as the "most important" as it is never empty. Then, stakeholders weigh the other criteria by comparing the most important criterion.

Weight allocations from all stakeholders in the group are collected. Suppose there are n criteria in the criteria set of the stakeholder group, the multiple-stakeholder profiles of criterion k rank on the class weight score i_c is w_{ki_c}, which means the proportionality of the criterion percentage profile of the class weights. By taking the arithmetic mean of the importance's classes, the not-normalized weight (NNW) of the criterion k is gotten:

$$NNW_k = \sum_{i_c=0}^{5} i_c \times w_{ki_c}; i_c = 0, 1, 2, 3, 4, 5 \tag{1}$$

Then the normalized weight (NW) of the criterion k is the NNW of criterion k proportional to the NNW set:

$$NW_k = \frac{NNW_k}{\sum_{j=1}^{n} NNW_j} \tag{2}$$

In this way, the global weight allocation of the stakeholders from the stakeholder group is calculated.

Alternative Evaluation. Suppose stakeholders have to evaluate a finite set of alternative $A = \{a_1, a_2, ..., a_m\}$, stakeholders are asked to give performance scores on the alternatives based on each criterion. A 5-point LS is used, and at least one alternative needs to be scored 5 as the "most preferred" for one criterion. The other alternatives are scored by comparing the most preferred alternative, which is treated as a benchmark. After collecting all the evaluation data, the performance percentage profile p_{tji} of alternative t on the class weight score i_a based on criterion j is gotten.

The calculation of the performance scores considers the profile distributions. to get the global performance indicator of an alternative a_t, say S_t, the global weight profile set $G_t = \{g_0, g_1, g_2, g_3, g_4, g_5\}$ needs to be calculated first:

$$G_t = \{g_{ti_a} = \sum_{j=1}^{n} NW_j \times p_{tji_a}\}; i_a = 0, 1, 2, 3, 4, 5 \tag{3}$$

Where i_a is the alternative performance score class. After obtaining the global weight profile set of one alternative, its global mean score V_t can be calculated:

$$V_t = \sum_{i_a=0}^{5} i_a \times g_{ti_a} \tag{4}$$

Still, the sole global mean score loses the important information concerning the profile dispersion, as the high deviation on the alternative performance scores will result in a nonconsensual solution among stakeholders. To obtain a safer ranking, the standard deviation of the performance score is considered. The standard deviation σ_t of V_t is given in:

$$\sigma_t = \sqrt{\sum_{i_a=0}^{5} g_{ti_a} \times (i_a - V_t)^2} \tag{5}$$

The final global performance indicator combines mean value and spread measured by the standard deviation:

$$S_t = V_t - \sigma_t \tag{6}$$

Only the lower value from the interval of the standard deviation σ_t is kept for being on the safe performance side.

The evaluation process of the MAMCA survey model is finished by now. The final weight allocation of the mass-participation stakeholder group can be used in the normal MAMCA evaluation process. However, it is advised not to include the alternative performance indicators as the final evaluation scores of the stakeholder group. Instead, the global performance indicators of alternatives should be treated as a reference to the stakeholders' preferences. It is believed that the criteria priority ranking is much more objective than the alternative evaluation. The alternative evaluation requires more objective data and information to support, so the process of the alternative evaluation needs to be executed preferably by the experts. Still, the decision-maker can compare the result of the evaluation of experts and the stakeholders' performance indicators for further investigating. E.g., they can have a discussion with the stakeholders on it to see what their potential misconception is, use it to determine communication focus on specific alternatives.

4   Case Study

In order to apply the MACMA survey model in practice, a survey tool is developed in the MACMA software. Dedicated pages for the survey tool are built, called "MAMCA survey tool" pages. Each MAMCA project has individual survey setting pages. And the decision-maker can publish the surveys dedicated to different stakeholder groups, in which different survey questions can be asked. Also, the decision-maker has an option to ask stakeholders to evaluate alternatives or not, while the weight allocation of criteria is a must.

To demonstrate the MAMCA mass-participation function, a fictive case entitled "The last-mile in the supply chain" is used. The case aimed to gain insight into the extent to which different alternatives for the last mile of a supply chain for home deliveries contribute to the interests of the different stakeholder groups involved. In this case study, there is a stakeholder group "citizens", that is suitable for validating the mass-participation function. In this study, only the stakeholder group "citizens" is focused upon. The data shown here are for demonstration reason only and are not the result of

Table 1. Criteria of stakeholder group "citizens"

Criterion	Criterion description	Direction of preference
Road safety	The low risk that a person using the urban road network will be (fatally) injured	Maximization
Air quality	Low concentration of particulate matter, NOx and SO2 in the air	Maximization
Urban accessibility	Reduce freight transport, less congestion	Maximization
Attractive urban environment	Attractive and livable urban environment for its citizens	Maximization
Low noise nuisance	Reduce noise nuisance of road transportation	Maximization

an actual survey that was performed among citizens. The criteria of the "citizens" group and the corresponding descriptions and directions of preference are shown in Table 1.

Before distributing the survey, a relevant question about the stakeholders' SES is raised: "Is there a significant difference on the criteria priority ranking between car owners and non-owners?". The decision-maker can ask these types of questions through the survey (see Fig. 6). Then, a survey page dedicated to this stakeholder group can be generated. Stakeholders need to rank the priority of the criteria. The decision-maker can choose if stakeholders are also allowed to evaluate the alternatives.
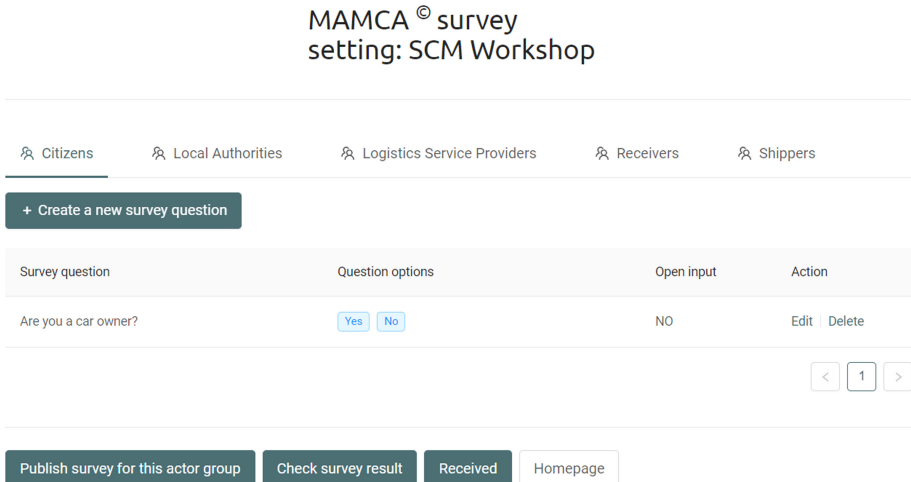
Fig. 6. The screenshot of MAMCA survey setting: design survey questions

4.1 Stakeholders' Perspective

The stakeholders receive the survey link that is sent by the decision-maker. The survey consists of 5 parts: Description of the project, overview of alternatives and criteria, answering survey questions (optional), weighing the criteria, evaluating the alternatives (optional). After going through the overview of the alternatives and criteria, they should answer the SES questions asked by the decision-maker. Next, the stakeholders need to give the importance scores to the criteria, and optionally, they will give the performance scores to the alternatives based on their preferences (see Fig. 7).
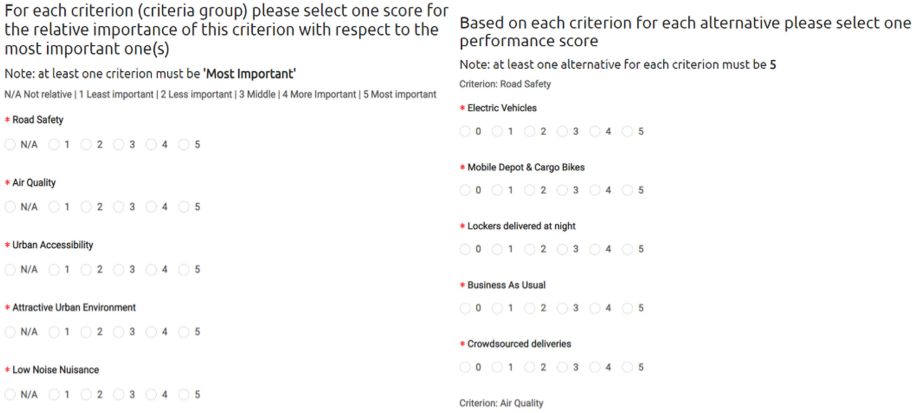

Fig. 7. Screenshots of the weight allocation and alternatives evaluation pages

The stakeholders do not need to log in to the software. By just answering the survey, the results will be registered.

4.2 Decision-Maker's Perspective

After invited stakeholders have finished the evaluation, the decision-maker can check the final result of the survey in the MAMCA software. As shown in Fig. 8, the table of the weights' distribution allocated by the stakeholders and calculated standard deviations are listed. In this example, it indicates that the criteria "Urban Accessibility" and "Attractive Urban Environment" have the highest NNWs; at the same time, these two criteria have the lowest standard deviations, which means they are the most important criteria in the points of view from the stakeholders. The NWs are the final weight allocation of the stakeholder group.

After all surveys are submitted and the quality of them are checked, the decision-maker can import the survey result to the MAMCA project by clicking one single button. The NWs of the survey will be treated as the weight allocation of the stakeholder group "citizens" and will be applied in the further evaluation of the MAMCA process.

Weights   Scores   Social-Economic profiles

Criteria Name	Not relative (0)	Least important (1)	Less important (2)	Middle (3)	More Important (4)	Most important (5)	Standard deviation	Not-normalize d Weight	Normalis ed Weight
Road Safety	-	-	13.3%	53.3%	13.3%	20.0%	1.0	3.4	18.6%
Air Quality	-	6.7%	26.7%	13.3%	20.0%	33.3%	1.4	3.5	19.0%
Urban Accessibility	-	-	6.7%	13.3%	40.0%	40.0%	0.9	4.1	22.6%
Attractive Urban Environment	-	-	6.7%	26.7%	13.3%	53.3%	1.0	4.1	22.6%
Low Noise Nuisance	-	13.3%	20.0%	20.0%	33.3%	13.3%	1.3	3.1	17.2%

< 1 >

Copy survey weight data to project

Fig. 8. Screenshot of the "citizens" group's weight table

As mentioned before, in this case study we would like to investigate if the car owners in the group "citizens" would have a different rank of criteria priority than those who do not own a car. In the MAMCA survey tool, the decision-maker can add comparison groups based on asked survey questions (see Fig. 9). Two groups are created based on if the stakeholders own private cars. A pie chart showing the proportion of the answers indicates that the stakeholders who own private cars are slightly fewer than those who do not. A bar chart is generated that shows the weight allocation of the criteria from the two comparison groups. It can be seen there is a large difference in the importance of the criterion "Urban Accessibility", that the car owners rank as the most important criterion among all, while the other stakeholders rank it as the least important. Apart from that, the other importance of the criteria is similar. It makes sense that, the citizens overall find an attractive and livable urban environment important, but the car owners suffer from over-busy traffic so they also think less congestion is really important.

The decision-maker can have a further discussion on it, as now the "citizens" group has two different criteria priorities because of urban accessibility. Two sub-groups could be divided into the "citizens" group based on the SES "Private Car Ownership". The corresponding criteria weights are allocated regarding the SES. In the afterward MAMCA alternative evaluation, experts can give more rational evaluation scores for two sub-groups concern about their interests.
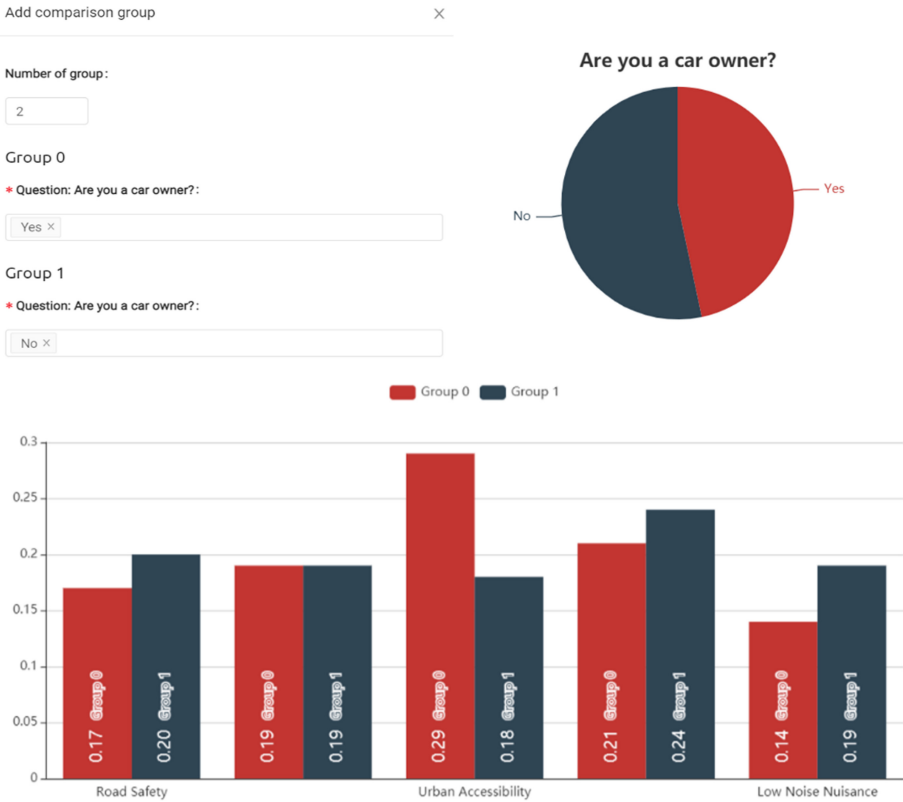
Fig. 9. Screenshots of the comparison function

5   Limitations and Directions for Future Research

This study tries to demonstrate the new MAMCA mass-participation survey tool. A fictive case is used in this study; it is a didactic case that was applied in the university. The students are the actors for different stakeholder groups as roleplays. In the end, 50 samples of the surveys are collected for the "citizens" stakeholder group. Still, there should be more responses of the voices as a mass-participation decision-making process. There are still a lot of potentials for this study. Two directions for the future research are listed below.

First is to have a study on a real "mass-participation" case. This paper mainly talks about the methodology of the mass-participation decision-making behind and focus on the presentation of the MAMCA survey tool. A mass-participation case in the real world concerns about sustainable urban construction logistics will be studied in the near future. By surveying the citizens in Brussels-Capital Region (BCR), Belgium, the opinions of the citizens can be gathered, and the mass-participation analysis can be applied. This mass-participation decision-making can be evaluated in this case.

Second is to have an in-depth discussion of the post process after gathering the survey. Due to a limited number of pages allowed, there is only a small discussion about

the sub-group creation and evaluation after collecting the data. A dedicated work will be done to discuss when and how to regroup the stakeholder group or divided the group into sub-groups based on the collected information, e.g., standard deviations of the weight allocations, SES.

6   Conclusion

MAMCA methodology now shifts the concept of the "stakeholder" to the "stake-holder group", trying to hear the points of view from more stakeholders, instead of those of only one representative in each group. Elaborate types of groups like "citizens" have some characteristics that are inefficiently addressed by the current participation system. The stakeholders within this group are normally hard-to-reach and have quite different SES. To involve more stakeholders and hear the voices of them, a new MAMCA survey model for the mass-participation is designed. The survey model divides the tasks of the decision-maker and stakeholders, such that they can work singly instead of being gathered in the workshop. PROSE method is used for the evaluation process. It is a transparent method that applies a weighted sum approach based on order statistics to combine the individual profile distribution. It is suitable for the mass-participation evaluation as it is easy to understand but also mathematically sound. Additionally, the decision-maker can inquire about the SES of stakeholders for further investigation within the stakeholder group.

Following this, a survey tool built in MAMCA software is developed. The survey tool can explore more detail within one single stakeholder group. As there is a massive number of stakeholders participating, their priorities might be different. The survey tool not only indicates the weight allocation of the criteria, but also the standard deviation of the importance scores given. The decision-maker is able to find the homogeneity and heterogeneity within the stakeholder group: By creating comparison groups, the weight allocation of the criteria from stakeholders with different SES are displayed in a bar chart. If there is a significant difference in the ranking from the stakeholders with different SES, the decision-maker should consider regrouping or identifying sub-groups for the stakeholders.

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