Fostering Collaboration on Decision Processes

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Abstract: Due to intrinsic complexity and uncertainty, decision problems require involvement of stakeholders with distinct backgrounds and points of view. Collaboration among stakeholders is then essential to identify the problem and find solutions. We propose a framework with guidelines to aid decision-makers, together with a facilitator, to structure and solve a problem collaboratively in a virtual environment. The framework points out how collaboration takes place during the whole decision process, including phases to structure the problem, to apply the multi-criteria decision analyses, and to explore the sensitivity analyses in order to reach the final result. We conducted an empirical evaluation, where decision makers reported benefits of the framework to engage stakeholders, to congregate ideas, and to reduce the duration of the decision process.

1 INTRODUCTION

Decision making is a very important topic discussed in operation research, including areas as transportation, scheduling, routing, supplier selection, and alternatives ranking. If the problem involves finding the best solution or optimizing the actual process, it is needed to identify the problem itself, generate correct criteria, and formulate a model to achieve the desired results (Rönnqvist, 2010). Decision-making processes are complex by their nature, since they usually involve uncertainty, multiple criteria, conflict of interests and distinct stakeholders (Saaty, 2008). By stakeholders, we mean people involved and affected by the problem, such as community, employees, company owners, clients, suppliers, governmental groups, and even society.

A decision-making process starts with a problem that stakeholders need to solve. It is needed to structure the problem in order to know the main objective and the ways to accomplish such objective (Montibeller et al., 2006). The first phase of a decision-making process involves the application of Problem Structuring Methods (PSMs) to systematically map and structure a situation to face. The second phase refers to the Multi-Criteria Decision Analysis (MCDA). MCDA aims to evaluate options taking into account distinct decision-makers with in general conflicting perceptions and goals (Goodwin and Wright, 2014).

In a group decision-making process, it is needed the collaboration of distinct stakeholders. Sometimes decision makers are people geographically dispersed or with restricted agenda, which makes difficult to gather them collocated. So, it is needed to conduct the decision process in a remote way. Most of the time, a neutral facilitator moderates the actions of decision makers to organize ideas. The facilitator then needs to aggregate information and give continuous feedback to decision makers. This practice takes time to be conducted, and sometimes it unintentionally loses or hides information that can be valuable to the group (Forman and Peniwati, 1998; Kamel and Davison, 1998; Ho, 2008; Angiz et al., 2011). In this way, it is of interest a way to aid online collaboration among decision makers and facilitators when performing decision processes.

In this work, we propose a framework to support online collaboration in executing decision processes. Decision makers can identify criteria and alternatives through PSMs, and to solve the problem using a MCDA. The main benefit of our proposal is the possibility of online collaboration during the entire decision process, without the need of being united in the same place or time. Other advantage is the real time visualization of information provided by decision makers, which allows them to engage and reach the identification of criteria and

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alternatives with better quality. There is also the possibility of collaboration considering the sensitivity analysis. It allows decision makers to view other scenarios and not only the result of the MCDA method, which is important to select the final decision.

We present a flux with the main activities of a decision process; we identify which activities are prone to collaboration and explain how online collaboration can be performed. We also present a prototype developed according to the guidelines established in our proposal. In order to evaluate the framework, we make an empirical application, where a group uses the prototype to identify the main activities to increase energy efficiency in the food and beverage industries.

Section 2 presents our background. Section 3 describes the proposed framework to support online collaboration in decision problems. Section 4 describes an empirical study to evaluate the framework, by using a prototype. Finally, conclusions and future work are presented in Section 5.

2 BACKGROUND

In this section, we discuss about problem structuring methods, multi-criteria decision analysis, and sensitivity analysis. We explain the concept of online collaboration and detail how it is used to support decision-making. We also present related work.

Problem Structuring Methods (PSMs) are usually applied in fuzzy situations where it is hard to identify reasons and goals intended to be achieved. PSMs help decision makers to think in a systemic way, not only on alternative focused thinking. PSMs are mostly categorized as soft operational research methods, involving dialog and scenario identification. Some examples are Value Focused Thinking - VFT (Keeney, 1992) and Value Focused Brainstorming - VFB (Keeney, 2012), Soft System Methodology - SSM (Neves et al., 2009), Strategic Choice Approach – SCA, and Strategic Options Development and Analysis - SODA (Mingers and Rosenhead, 2004). These methods are based on qualitative and diagrammatic modeling, in a way that they allow the exploration of distinctive views and the incentive of active participation by stakeholders. The goal of these methods is not only optimization; instead the goal is to explore the problem scope, to identify the uncertainties and to get commitment of the stakeholders. In this paper, we choose Value Focused Thinking (VFT) and Value Focused Brainstorming (VFB) as the PSMs. The reason is that such methods emphasize the stakeholders' values. Such values are related to the way of acting and thinking, socially and ethically.

Regarding the Multi-Criteria Decision Analysis (MCDA), there are several techniques to support it. These techniques do not always give the optimum solution, but they help to evaluate alternatives to reach the given objective. Some examples are SMART (Goodwin and Wright, 2014), Analytic Hierarchy Process (AHP) (Saaty, 2008), MAUT, MACBETH, PROMETHEE, ELECTRE family, TOPSIS, DEA and Goal Programming (Ishizaka and Nemery, 2013). In this paper, we choose AHP as the MCDA technique. AHP has been used in different purposes, including optimization, planning improvements in industrial plants, and selection of best alternative among several ones with different characteristics. AHP is widely used because it is practical and well accepted by various industrial sectors. As result, AHP provides an ordered list of alternatives based on the used criteria (Vaidya, O., and Kumar, 2006; Steuer, 2003). In order to provide better accuracy in possible different scenarios, it is also important to make a sensitivity analysis, to visualize other possibilities of criteria weighting (Jalao et al., 2014). The final decision of the decision process is usually made considering the MCDA output, but decision makers must take the last decision.

Online collaboration can be useful to mitigate group interaction problems such as those related to time, cost, distance and space. Gathering people together can be complicated due to incompatible agendas or logistic costs. The geographical distance between people and the space needed to allocate people together are also limiting problems to interaction. Regarding online collaboration in decision-making processes, Fiedler et al. (2014) developed a tool called SeSAM e-democracy. It is an online platform for modern parliamentary work to solve problems. It allows online public and private meetings, supporting discussions and documents' development.

According to Siskos and Spyridakos (1999), systems that support decision-making processes consist basically of three components: a database, a core model and a communication system. The database manages data provided by decision makers, storing and processing information. The core model includes the structure and algorithm of the method used to aid multi-criteria decision. The communication system is designed to support communication between the decision makers. Users communicate and cooperate to insert information in database, so the software can calculate the final results. It exemplifies the collaboration among decision makers in decision-making processes.

Collaboration in decision-making processes also happens due to the existence of facilitation. Santanen et al. (2004) explain that the facilitator, during a decision process, can help in cases of divergence (when group disagree on ideas), convergence (by identifying opportunities to improve ideas), organization (by understanding the relationships among concepts), evaluation (by understanding priorities toward goal achievement), and consensus building (by identifying opportunities to have less disagreement on courses of action).

Some approaches aim to support MCDA, for instance Super Decisions (2016), WBMCDM (Al-Azab and Ayu, 2010), 123AHP (2016), EasyMind (2016), Criterium Decision Plus (2016), Expert Choice (2016), MakeItRational AHP (2016), Decision Lens (2016), RightChoice DSS (2016), and Questfox (2016).

Super Decisions is a desktop-software that allows decision makers to solve problems using ANP (Analytic Network Process) and AHP methods in a collocated way. It provides sensitivity analysis at the end of the calculations, however does not allow making a group aggregation and structuring the problem. The WBMCDM (Web Based Multi-Criteria Decision Making) system is an open source solution for solving AHP. It is a simple web interface that allows only one decision maker to insert criteria and alternative limited by 5 and 3, respectively. The WBMCDM is very similar to 123AHP, which in turn is but limited since it does not allow group interactions or problem structuring.

EasyMind is a web base system that can work offline on web browser. The system does not allow group aggregation neither problem structuring. It has a non-collaborative sensitivity analysis. Criterium Decision Plus is a desktop-software to solve AHP and SMART, but it does not allow group evaluation. Expert Choice, MakeItRational, Decision Lens, RightChoice DSS and Questfox are desktop or web based platforms to aid multi-criteria decision-making using AHP. However, they do not allow problem structuring in their interface, and their sensitivity analysis does not support collaboration.

Limitations are found in current approaches mainly due to problems regarding collaboration. The approaches regarding MCDA do not deal with Problem Structuring phase in group decisions, so that there is no available way to discuss criteria and alternatives, which in turn restricts collaboration among decision makers. As decision-making processes in groups need to calculate the aggregation of individual judgments (AIJ), it is important that the system calculate using the correct method of aggregation. Some approaches are limited by not providing collaboration during AIJ, since they focus only in aggregating preferences. Usually sensitivity analysis is made by a system that calculates priorities aiming to show other points of view. In this phase, it is also desirable collaboration in order to improve understanding of MCDA results by decision makers. Our proposal aims to fill the identified gaps for the purpose of fostering collaboration in decision problems.

3 A FRAMEWORK TO SUPPORT ONLINE COLLABORATION IN DECISION PROBLEMS

In this section, we propose a framework to help the collaborative execution of a decision process in an online environment. The framework is composed by activities. We explain each activity and detail where collaboration occurs. The proposed framework is presented as a workflow in Figure 1.

The framework has two main phases. The first phase is problem structuring, when decision makers, aided by the facilitator, acting as a group, use VFT and VFB methods to identify the main decision goal, the main objective, the distinct criteria to be considered in decision, and the possible decision alternatives. The second phase is the multi-criteria decision analysis, where APH is used as the MCDA technique. After the two main phases, the decision-making process continues with sensitivity analysis. Finally, decision makers discuss the final decision considering the output of AHP calculation. In the framework, the white boxes with solid contour are activities that need someone (decision makers or facilitator) to be performed. The white boxes with dashed lines are activities that can be made automatically without intervention of facilitator and decision makers. The gray shapes represent the activities where collaboration occurs. All activities are described in the sections below.

3.1 "Understand the Problem" Activity

The first step to solve multi-criteria problem is to understand the problem itself. The idea here is to have a brainstorming among decision makers, but moderated by the facilitator. To start the activity, the

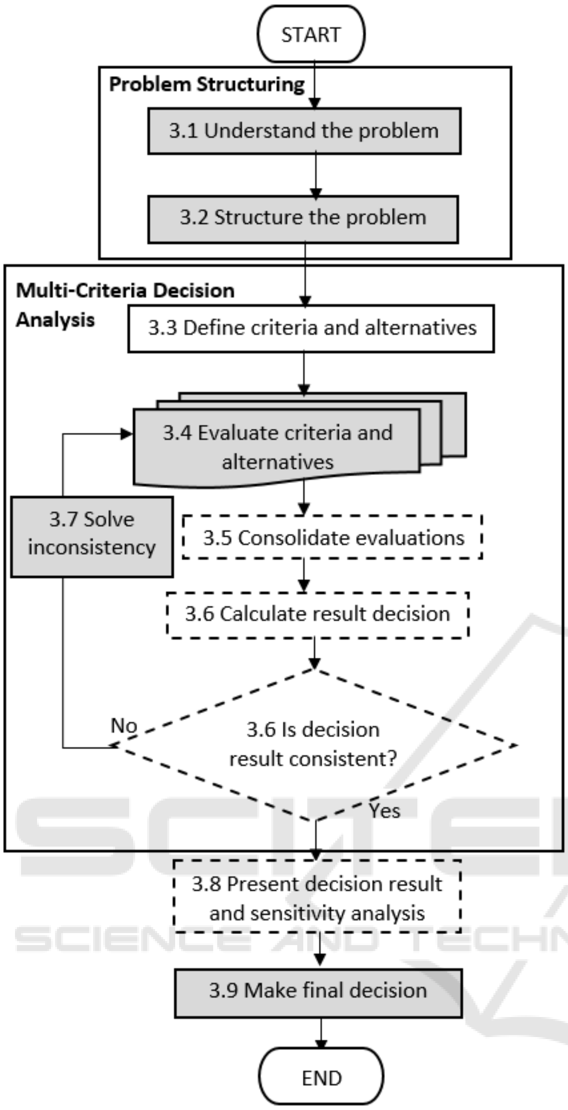

Figure 1: Decision process flow with collaboration.

facilitator creates the users and respective passwords to access the framework. The facilitator also defines how long the activity is active and verifies such deadline continuously.

In our framework, we use Value Focused Brainstorming (VFB) as a method to understand the problem. The values may vary from one decision case to another. For example, in a problem involving energy efficiency, the conscious use of electricity can be a value. Considering an employee management problem, the ethical actions of a person can be values. Each organization has its values associated with its mission (the purpose of the organization) and vision (how the organization wants to be seen in the future). The values are the main principles that guide individual actions. It is important that the decision makers and the facilitator focus on the real problem, guided by the main objective, with the values of the organization and society, ethical alternatives and valuable criteria to achieve the identified main goal. More details about VFB can be found in Keeney (2012).

The collaboration occurs in a way that each decision maker can give his opinion on an identified value added by others. Giving grades, increasing information or simply explaining other point of view for the given information. Each information provided by a decision maker is available for other decision makers, who can evaluate (for instance, with grades from 1 to 5, where larger grades indicate more relevance) and make further comments. According to the facilitator experience, in the subject considered in the decision process, it is also recommended to allow the facilitator to collaborate as a decision maker. When the defined time is over, the facilitator closes the activity to structure the hierarchy on the next activity.

3.2 "Structure the Problem" Activity

After VFB application, the facilitator must organize the submitted ideas using the VFT hierarchy. Usually it can be made by clustering information in order to obtain multiple criteria. The criteria are the mean objectives that must be accomplished to achieve the main goal. The main goal is the fundamental objective in a VFT approach. The alternatives are the possibilities to attend criteria to achieve main goal. More details about VFT can be found in Keeney (1992).

The structured problem can be viewed as hierarchies of objective, criteria and alternatives. The organized structure information, displayed in a hierarchy chart, makes the decision makers to understand the criteria and alternatives involved in the decision process. The decision makers can then collaboratively validate this structure, giving their points of view on different organization of decision tree.

3.3 "Define Criteria and Alternatives" Activity

Once the VFT hierarchy is completed, the facilitator can insert in the framework the criteria and alternatives to provide a way to decision makers evaluate them. It is a layout transformation of information, the mean objectives are now seen as criteria, and the possible alternatives to achieve each mean objective are the multi-criteria alternatives.

3.4 “Evaluate Criteria and Alternatives” Activity

Since criteria and alternatives are identified, they are submitted to decision makers’ evaluation. Each decision maker individually evaluates criteria and later alternatives in a pairwise way, which means that he/she compares two items at time. It is important that the decision makers think about the best solution for all involved stakeholders, sometimes making tradeoffs of their own opinion. It is made using the fundamental scale provided by the AHP method, from 1 (equal importance) to 9 (extremely more important).

The collaboration between facilitator and decision makers tends to avoid a future inconsistency after information consolidation. It is done by the verification of completed evaluations, requested by the facilitator to decision makers. The idea is to mitigate incoherencies by sharing ideas, opinions and tradeoffs. The facilitator also verifies if the evaluation is completed.

3.5 “Consolidate Evaluations” Activity

Once all decision makers provide their information comparing criteria and alternatives, the evaluations must be consolidated in order to create an aggregated pairwise comparison matrix. This matrix uses the AIJ method, as all decision makers desire to solve the structured problem thinking on the best solution for all instead of choosing its priorities. Judgments are unified by calculating geometric mean of decision makers’ evaluation of criteria and alternatives, considered by each criterion.

3.6 “Calculate Result Decision” and “Consistency Verification” Activities

The AHP method can calculate the consolidated matrix in order to provide the priorities vectors of criteria, alternatives and global priorities. Other important information, provided by AHP, is the consistency of the matrix. The consistency is a rated value to check if the information makes sense through given evaluation. Details of calculations related to APH method can be found in Saaty (2008).

The facilitator compares the output of consistency calculation. If the consistency verification fails, the criteria and alternatives must pass through other pairwise comparison by those decision makers that evaluations caused inconsistency. It is described on the “Solve Inconsistency” activity. If the succeeds, the decision result and global priorities are presented to decision makers.

3.7 “Solve Inconsistency” Activity

If the consistency check gives a negative result, the inconsistency must be solved. The facilitator requests decision makers to review their evaluations pointing out the problem, opening the inconsistent evaluation made by decision makers stored in database.

Sometimes the problem occurs after aggregation of judgments, representing conflicting ideas between decision makers. The facilitator must identify where it happened in order to avoid other problem after the evaluation of criteria. It may be made through his experience with the specific methodology, in order to bring the information to the consistent values and not to change the evaluation drastically.

3.8 “Present Decision Result” and “Sensitivity Analysis” Activity

The sensitivity analysis receives the ordered (ranked) result of AHP. A graphic presents intersection points of turnover of an alternative priority to another. It can be seen different scenarios for other situations of weighting criteria and possibly a completely different selection of alternatives. Details of calculations related to sensitivity analysis can be found in Jalao et al. (2014).

The main idea is that the facilitator can provide a textual interpretation of the data, and open for discussion, since the result of AHP only points the best solution for evaluated criteria and alternatives. It can be hard to extract important data for those not familiar with the output of the sensitivity analysis, so providing information such as “alternative 1 turnovers 2 above 40% of criteria ‘x’ weight” is very helpful.

3.9 “Make Final Decision” Activity

With the sensitivity analysis and ordered alternatives by AHP, decision makers can work on solutions in a collaborative way. Sometimes the decision group can be controlled by other factors such political force and investment policies. Therefore, decision makers must be able to choose or even select a reduced group of alternatives to solve the problem.

In addition, the MCDA method only helps to organize and rank alternatives based on previous evaluations. It aids the analysis of multi-criteria problems, but the decision group makes the final decision. They may also freely discuss positive and negative point of ranked alternatives.

4 EVALUATION

In this section, an empirical application is provided to evaluate the proposed framework by using a prototype. We choose energy efficiency problem in our study, since it is a relevant issue for the industry in all fields of production, for instance supply chain, manufacture and agro industrial sectors. Nowadays, research has been conducted to find alternative sources of energy to power the scattered grids all around the globe, in a way to increase energy efficiency.

4.1 Prototype

In order to support groups for using the framework in multi-criteria decision processes, a prototype was developed. It is a web application on ASP.NET MVC 4. The ASP.NET is a framework developed for creating web pages. It helps web designers to create connections between database storage system and the visualization part of a web page, using MVC (Model, View, and Controller) model.

A database storage system called SQL (Structured Query Language) Server is used to store user data and information provided by problem structuring and pairwise comparison. The algorithm for calculations is written in C# language. The visualization part uses JavaScript, CSS (Cascading Style Sheet), HTML and ASP.NET Razor.

4.2 Design of the Empirical Application

We worked together with an institution in our country, which has energy efficiency solution as an important service in its portfolio. The institution also has strong interfaces with food and beverage industries in the region where it operates. The objective of the empirical application was to identify common characteristics in local industries and prioritize services to be offered, considering a fast impact on energy efficiency issues.

We had six participants in the empirical application. One participant was a consultant from the institution and he act as facilitator. Five others participants were decision makers. From two distinct food and beverage industries, we had two production managers and two maintenance managers. The other participant was a consultant of energy topics. The decision makers worked together using the developed prototype.

The effectiveness of the framework was evaluated through a set of questions before and after the usage of prototype. The decision makers answered questions about their experience, considering the easiness to understand a problem, the time taken in a decision-making process, the easiness of engaging people; and the easiness of expressing themselves. They used the five-point Likert scale: 1 (poor), 2 (fair), 3 (average), 4 (good), and 5 (excellent).

4.3 Results

On the problem structuring activity, decision makers provided information and evaluated it in order to generate criteria and alternatives. The values that guided decision makers on information were proposed by the facilitator: Productivity; Process efficiency increase; Competitiveness; Environment preservation; Workers security; and Compliance with regulation. The resultant hierarchy structure for this particular problem drive the identification of criteria and alternatives described below.

During the multi-criteria decision analysis activity, the decision makers then identified five criteria: Energy management (how the industry uses the energy to manufacture consumer goods), Knowledge (the expertise on energy efficiency), Energy quality (the quality of electrical energy provided by the electrical energy company), Equipment (how efficient equipments are in a production line), and Processes (how efficient a process is when consuming energy). Regarding the alternatives, decision makers chose services that can be offered to industries, including: Optimization and Layout, Diagnostic, Automation and Refrigeration, Maintenance and Retrofit, Regulation Attendance, and Education. Considering the AHP results and the sensitivity analysis, decision makers agreed that Education services are the most needed by their industries, followed by Optimization and Layout Changes services.

Table 1 shows the results of evaluations made by decision makers before and after using the framework.

Regarding the easiness of criteria identification, the evaluation shows an increase of grades. It shows that, using the framework, decision makers could identify the multiple criteria involved through a discussion oriented by value-focused brainstorming. Comparing the evaluation of time taken in a

Table1: Framework evaluation driven from empirical application.

Topic	Before framework	After framework
Easiness of criteria identification	1.6	4.4
Short time taken in decision-making	2.6	3.8
Easiness of expressing themselves inside group	3.2	4.4
Easiness of alternative identification	3.4	4.2
Easiness of engaging team in decision-making	1.8	4.8
Potential to use the framework on daily decision-making	NA	4.8

*NA means not applicable

decision-making process, the framework allowed decision makers to work collaboratively in a shorter time. The easiness of expressing themselves inside the decision group also increased, since decision makers could give their opinion and make their own evaluations during the decision process. The easiness of alternative identification also increased using the online framework. A positive impact on decision-making process was related to the easiness of engaging decision makers in the process, since they were able to work in despite of time or location difficulties. Moreover, decision makers evaluated positively the possibility to use the framework in other decision processes that they participate. Decision makers also cited the main advantages of using the framework, as seen: fast information input, possibility to evaluate each point of decision, possibility to generate innumerous alternatives, individual evaluation of criteria and alternatives, structured visualization of decision process, remotely engagement of the team, and reduction of time taken for the decision-making process.

5 CONCLUSIONS

Working with multi-criteria decision problems is complex since many uncertainties are involved. We proposed a framework to foster collaboration in multi-criteria decision processes, and so to help reaching better and complete decisions take into account distinct perspectives of stakeholders.

The proposed framework considers a collaborative problem structuring method to make all the criteria and alternatives clear and available for discussion. Decision makers then collaborate to identify criteria and alternatives to the decision process. Decision makers complete pairwise comparisons, mediated by the facilitator, as part as the multi-criteria decision analysis. If any inconsistency in result occurs, it is provided a way to facilitator and decision makers re-evaluate the pairwise comparisons. Considering the sensitivity analysis of the problem, facilitator interprets the information for decision makers. Therefore, decision makers discuss the result encouraged by online collaboration, making the final choice of a problem.

The framework is useful to identify involved criteria and alternatives in decision-making process; it aids to solve multi-criteria problems of ranking several alternatives when multiple criteria cause uncertainty; it helps to visualize different scenarios when the problem is sensitive to criteria weight changes; and it allows discussion among decision makers to make the final decision. Problems that have such characteristics are related to ranking of alternatives, selection of suppliers, identification of best delivery route, selection of industrial machinery and many operational research problems.

The developed prototype assures the viability of the framework. It provides a collaborative interface where decision makers, together with facilitator, may structure a problem, analyze the multi-criteria, interpret the sensitivity analysis and make final decision. All the phases are implemented through the guidelines available on the online framework.

To evaluate the prototype and therefore the framework, an empirical application in energy efficiency was conducted. Decision makers evaluated their experience with decision processes before and after using the framework. They indicate improvements on these processes when using the framework. All aspects were considered better when using the framework, as seen: easiness of criteria identification, short time taken in decision-making, easiness of expressing themselves inside group, easiness of alternative identification, and easiness of engaging team in decision-making.

As future work, we aim to conduct empirical applications in teams with more decision makers. We intend to evaluate the priority of services on other industry sectors, not only focusing in food and beverage industries. It is also possible to incorporate other methods during both the problem structuring phase and the multi-criteria decision analysis.

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