Water Resour Manage (2018) 32:2955–2968
https://doi.org/10.1007/s11269-018-1966-9

# An Approach for Supporting Problem Structuring in Water Resources Management and Planning

**Vanessa B. Schramm**[1] · **Fernando Schramm**[1]

Received: 14 June 2017 / Accepted: 13 March 2018 /
Published online: 21 March 2018


**Abstract** The watershed committees in Brazil often face difficulties to find out consensus solution for problems in water resources management and planning, due to multiple participants with different backgrounds, differences of opinion, conflict of interests and differences in perceiving and interpretation of problem and solution. This situation results in conflicts and consequently put activities of committees at risk. The Problem Structuring Methods – PSMs are techniques to structure problems and analyze similar type of problems. PSMs offer a way of representing the situation to provide clarity to participants in understanding the problem and lead to converging on potential agreeable actions for at least partial resolutions. This paper presents a group decision approach for supporting water resources management and planning, based on the use of the PSM Strategic Options Development and Analysis – SODA, which performs the cognitive mapping of individuals. The approach promotes a common understanding about a complex situation under investigation, assisting the group in identification of a course of actions for solving the problem. The approach is intended to support Brazilian watershed committees and it was applied to the committee of the Paraíba River watershed in northeastern Brazil. Using this approach, the committee identified inadequate watershed management as a major issue that must be undertaken in order to achieve mitigation of watershed degradation.

**Keywords** Group decision · Problem structuring methods · Cognitive mapping · SODA · Watershed committee

## 1 Introduction

In Brazil, the management and planning of water resources is based on a participatory model, in which a committee composed of representatives from water resources users, civil society

✉ Vanessa B. Schramm
vbschramm@gmail.com

[1] DeSiDeS (Development of Systems for Supporting Sustainable Decisions), UFCG (Federal Univiversity of Campina Grande), R. Aprígio Veloso, n.° 882, Bloco CB (REENGE), Bairro Universitário, Campina Grande, Paraíba 58.429-900, Brazil

and government is responsible for all decisions regarding a watershed. These committees often face difficulties to find out consensus solution for problems in water resources management and planning. Furthermore, the group itself is very complex since it involves individuals with different points of views and conflict of interests. In this messy environment, which is likely to generate conflicts, decisions and actions of the committee can produce positive or negative impacts on economics, society and environment. Therefore, as observed in practice, to ensure an effective decentralized and participatory management of watersheds in Brazil, the institution of the committees is not enough. It is necessary to provide a formal approach for supporting the activities of these committees.

The existence of multiple actors, with different perspectives, conflict of interests and a high level of uncertainties characterize such situations as unstructured complex problems (Mingers and Rosenhead 2001). There are techniques to structure problems and/or analyze complex decisions, some of which are characterized as the Problem Structuring Method – PSM. According to Mingers and Rosenhead (2004), PSMs offer a way of representing a situation, enabling individuals to clarify their problematic situation, making possible to achieve agreements regarding ways to at least partially resolve it.

In fact, the studies published in the specialized literature in the last ten years endorsed that PSMs are powerful tools for supporting problematic situations, such as problems handled by Brazilian watershed committees. Some examples of applications are cited in: Hjortsø (2004); Liao (2008); Levino and Morais (2011); Silva Filho et al. (2014); Manso et al. (2015); Medeiros et al. (2017).

Ackermann (2012) presents a study that examines the benefits gained from the use of these methods. The first benefit pointed out by the author is the ability for managing, rather than reducing complexity, which is particularly useful to promote a common and holistic understanding about the problem and a deep exploitation of it; he concludes that this aspect of PSMs is desirable in decisions, whose consequences in one part of the system affect other parts. The second benefit is the consideration of different points of view in a structured and effective manner, promoting ownership and commitment among participants; as a consequence of this, individuals understand that there is no single correct point of view and that by attending to the perceptions of others, the group not only enhances the quality of the outcome but also learns more about themselves, the organizations, and other world views. Consequently, other benefits emerge, such as, PSMs support a group's negotiations towards an agreed outcome and reduce the possibility of conflicts.

However, the author also observes that PSMs do not provide a single recommendation, but only insights. In fact, they are useful to support the first stages of a decision-making process, in which decision makers need to understand the decision problem and formulate it in terms of alternatives and evaluation criteria. Liao (2008) concluded that combining quantitative and qualitative methods is a trend for future work on PSM matters. Therefore, the use of a PSM combined with an appropriate decision support approach, considering qualitative and quantitative aspects during the evaluation and recommendation stages, can significantly improve the decision-making process and the quality of the final decision.

A quantitative technique that has been successfully applied to support complex decision-making processes is the Multi-Criteria Decision Making/Aid – MCDM/A. According to Hajkowicz (2008), MCDM/A provides a transparent and effective evaluation of alternatives. It has been widely used for supporting natural resources management and planning, particularly, participatory water resources management and planning (Coelho et al. 2012; Roozbahani et al. 2012; Mutikanga et al. 2011; Fontana and Morais 2013; Liu et al. 2013; Karjalainen et al. 2013).

Regarding the use of MCDM/A in the context of watershed committees, Silva et al. (2010) proposed a group decision support system model, based on the multi-criteria method i.e. Preference Ranking Organization Method for Enrichment Evaluation – PROMETHEE (Brans and Vincke 1985) that prioritizes alternatives, considering all the sustainability pillars and taking into account the background of water resources users, civil society and government.

The proposal of Silva et al. (2010) has four steps: the first step is intended for structuring the decision problem; the evaluation step, where the PROMETHEE II method is used; the aggregation step to obtain the ranking of the committee; and the last step for resolution of conflicts. The first step is the more critical because it requires an effective management of all the factors that make the environment complex to promote a comprehensive appreciation of the situation. However, the model doesn't provide any formal approach for supporting this step, revealing its weakness for real life applications.

Therefore, the goal of this paper is to present a group decision approach for supporting the stage of problem structuring in participatory water resources management and planning, based on the use of SODA. The approach is intended to support Brazilian watershed committees and it was applied to the Paraiba River committee in northeastern Brazil to structure a discussion about the degradation of the watershed. For the case study, the cognitive map of the committee was obtained through the aggregation of cognitive maps of a representative of a local industry, a government employee, who works at the Brazilian National Public Health Foundation and a civil society representative, who works at a federal university. The approach helped the committee to gain a common understanding about the problem and to identify that lack of adequate watershed management is the major issue that must be tackled for mitigation of the problem.

## 2 Background

The basis of any PSM is to represent points of view of individuals or a group in a diagrammatic form; then, these diagrams are exploited by the group, using different techniques, whose main objective is to promote the development of a common and enhanced understanding about the system, supporting participants in the achievement of an agreement regarding actions to resolve a problematic situation at hand (Ackermann 2012). To put it simply, Rouwette et al. (2011) say that PSMs support stakeholders in dealing with ill-defined problems. According to Morton et al. (2003) *apud* Rouwette et al. (2011), the term model-driven methods can be applied to PSMs, since these methods combine modeling and facilitation.

The PSMs emerged in the mid-1960s onwards in response to some limitations of traditional Operational Research – OR methods (known as hard-OR) that were reported by its users (Ackermann 2012). Through the years, several PSMs were proposed and have been extensively developed (Rouwette et al. 2011). Three of them have been used in a very high number of practical applications, with an increasing number of publications in scientific journals: Strategic Choice Approach – SCA (Friend 2001), Soft Systems Methodology – SSM (Checkland 2001) and SODA (Ackermann and Eden 2001, 2010; Eden and Ackermann 2001), which was devised by a group of researchers at the end of the 1980's.

From the perspective of decision makers, these PSMs are very similar to each other: typically, they provide the basis for a series of structured discussions that are conducted by a facilitator, who should be able to capture the essence of these discussion, being as impartial as possible, and then supporting individuals to organize and describe their ideas to the group.

To do this, SODA, which is one of the most prominent PSMs (Georgiou 2011), uses cognitive mapping to capture and record the perceptions that an individual has about a problematic situation (Ackermann and Eden 2001, 2010; Eden and Ackermann 2001). SODA maps are based on the idea of constructs of George Kelly's psychological construct theory (Ackermann and Eden 2001, 2010; Eden and Ackermann 2001; Georgiou 2011); thus, term "concept" of cognitive map theory is labeled "construct" in SODA (Caruzzo et al. 2015). Constructs are used to model the knowledge of the decision maker. After the elicitation of constructs and identifying the logical dependence among them, constructs should be categorized into six types: tails, heads, strategic options, implosions, explosions and dominants.

Individual maps are constructed during semi-structured interviews or discussions between the facilitator and the stakeholder concerned. These maps can be aggregated to provide a summary of the perception of the group (Eden 2004), that is, the cognitive map of the group. To do this, the facilitator should be able to identify constructs that represent similar issues and then group them in a cluster of constructs regarding a specific thematic. These clusters will form the points that link one individual map to another and hence allow the emergence of the group map.

The construction of the group map in SODA adopts the output level aggregation approach; in other words, each supra decision maker constructs his/her own map, which will be aggregated with other maps to construct the map of the committee. However, it is possible to construct the map of the committee considering an input level aggregation approach to aggregate individuals' preferences/points of view, when there is little divergence amongst members of the group; in these cases, an open discussion with the group is established and they are asked to agree on constructs and relations to create the group map.

In both cases, the group map may not reflect the opinion of each individual about the problematic situation. In this sense, the facilitator should ask the group for validation of the map in order to decrease the divergence amongst members of the group. SODA is not intended to provide a total consensus, but a means for concretely visualizing the understanding that the group has about the problematic situation at hand, including (and specially) the points of divergences among individuals and others that might otherwise have remained obscure, allowing for an appreciation of the understanding of others.

The map of the group is means for investigating problematic situations and its exploration can help on the identification of actions to solve the problem, which is one of the main steps in any decision making process. SODA is being used to support different types of decision-making processes; the next section presents some related studies that were published in specialized literature in recent years.

### 2.1 Literature Review

Regarding the use of PSMs in practice, Mingers and Rosenhead (2004) performed a literature review of relevant scientific journals that covered studies published between 1991 and 1998. According to the study, during this period, a total of 49 papers were published, which were classified into five areas: General Organizational (21); Information systems (6); Technology, resources, planning (9); Health services (9); General research (4). The review indicated the predominance of SSM; this methodology (alone or combined with other methods) appeared in 26 applications, while the use of cognitive maps appeared in 9 studies. The authors also presented four extra published case studies involving the use of PSM to support a high-profile client from outside the OR area: (i) Organizational restructuring at Shell based on the use of

SSM; (ii) Developing models for supporting damage claims, in which SODA was used as a technique for knowledge acquisition, serving as a raw-material for developing a systems design-based model; (iii) Supporting tenants co-operative, in which elements of different PSMs were used; and (iv) Developing an information technology strategy for supermarkets, in which a multi-methodology based on SODA, SSM and SCA was used.

As far as SODA applications are concerned, the review performed by Mingers and Rosenhead (2004) was not exhaustive. Other publications regarding the use of SODA can be found in the literature between 1991 and 1998, for example: Simpson and Beeby (1992) used SODA to support senior management groups in the Public Sector in the processes of organizational transformations; Bryant (1997) used the SODA for system requirements elicitation within a development project. In the last fifteen years, the number of publications regarding the use of SODA has increased, particularly for supporting problematic situations regarding environmental management. Some of these studies are presented below, whose description also helps to explain how the methodology works.

Eden and Ackermann (2004) applied SODA for identification and exploitation of potential policy options pointed out by individuals outside the prison department in the United Kingdom. According to them, SODA is not a method for supporting group decision making, but a technique for handling analytically complex problems.

Hjortsø (2004) applied SODA to increase the participation of society during the planning of strategic forest management in Denmark. The author proposed the application of a questionnaire in order to have the feedback of the thoughts of the interviewees about the usefulness of the catalogue. Moreover, a questionnaire to the council members was created and the results presented in a table to evaluate the feasibility of SODA approach in the process.

Levino and Morais (2011) proposed a model for supporting a group of individuals in the structuration and identification of alternatives to reduce sanitation problems that occur in Brazil. For evaluation of alternatives, Copeland voting procedure method was applied for selection of the best alternative. The model was not applied in practice to a real situation.

Rouwette et al. (2011) compare SODA with a system dynamics modeling approach, named Group Model Building – GMB, considering the same real-life case, with a similar group of individuals. On a theoretical level, the authors concluded that GMB and SODA are very similar: in both methods, participants list concepts central to the issues of interest and then relate them using a set of connected arrows. On the other hand, on a practical level it was concluded that SODA's major strength is its ability to identify and relate actions to indicate what must be done to achieve a given goal, while the GMB's major strength is its ability to capture the main structure that is provoking a problematic behavior. The authors concluded that GMB and SODA catch different aspects of the problem and they may complement each other: the former helps to create insight into the relation between (past) behavior and the structure of the problem while SODA is intended to identify actions.

Silva Filho et al. (2014) applied SODA to investigate criteria that should be considered for efficient allocation of segmentation valves in a water distribution network. They combined SODA with a MCDM/A approach, based on the method PROMETHEE II. The proposal considers 4 stakeholders: public relations analyst, environmental analyst, financial analyst and a supra decision maker who is a maintenance analyst. The proposal was not applied in practice to a real situation.

Almeida et al. (2014) proposed an approach for aggregating opinion of multiple stakeholders based on the use of Value-Focused Thinking – VFT (Keeney 1996) combined with the cognitive maps of SODA to solve a problem regarding the identification of selling price

strategies in a compounding pharmacy in Brazil. SODA was used to identify the problematic situation and to extract from the aggregated map the objectives of the group. According to the authors, the combination of both methods aims to explore the strength of each and assure a richer value structure resulting from the aggregation of different points of view.

Caruzzo et al. (2015) applied SODA to structure the problematic situation involving the use of weather forecasts for mission launching of aerospace vehicles in Brazil. For the mapping, the stakeholders were grouped as follows: (i) professionals of weather forecasts and meteorological observations; (ii) professionals who use the meteorological information during launch missions; and (iii) top decision makers who are senior managers in the launch missions. According to the authors, SODA enhances the understanding about the problem improving the quality of its analysis.

Manso et al. (2015) used SODA to structure the problematic issues regarding the management of natural disasters that occur in São Paulo, Brazil, by the civil defense system. For this, the stakeholders were divided into six groups, according to the areas of the civil defense system.

Dias et al. (2016) presented a case study in which the cognitive mapping technique was applied for the requirements elicitation process in aerospace product development in Brazil. Four cognitive maps were constructed using the CmapTools software, one for each decision maker (two clients and two suppliers). Based on the aggregated map, a tree of major points of view was created with eight branches that encompass similar concerns. Then, decision makers used this tree as an input to the process of product requirements elicitation.

Medeiros et al. (2017) presented a virtual case study in which a watershed committee is dealing with a conflict that emerged from a discussion about water pollution. The virtual case study is divided into three phases: pre-negotiation phase, in which the method SODA is used to identify relevant factors; multi-criteria evaluation phase; and post-negotiation phase for evaluation of agreement effectiveness. According to the authors, in this study an approach was proposed, however, its description is not sufficiently informative to allow its replication to other cases. Finally, due to characteristics of Brazilian watershed committees, the chance of application to a real situation is very low.

Oliveira et al. (2017) also combined cognitive mapping with a MCDM/A approach for evaluation of small- and medium-sized enterprises and their risk of bankruptcy, based on background of managers and bank analysts.

## 3 The Proposed Approach

This section is intended to present the proposed approach. The approach for structuring problems aims to promote a common understanding about a problematic situation discussed in a committee for water resources management and planning, supporting the group to identify and agree on a set of strategic actions/alternatives for mitigation of the problem. The goals are: to identify a complex problematic situation that is being addressed by the committee; to select individuals who will represent each interest group in the construction of cognitive maps; to identify a set of strategic actions for solving the problematic situation at hand.

The approach is divided into five stages (Fig. 1): (i) regular committee meetings, for identification of a complex problematic situation; (ii) first workshop for presentation of the

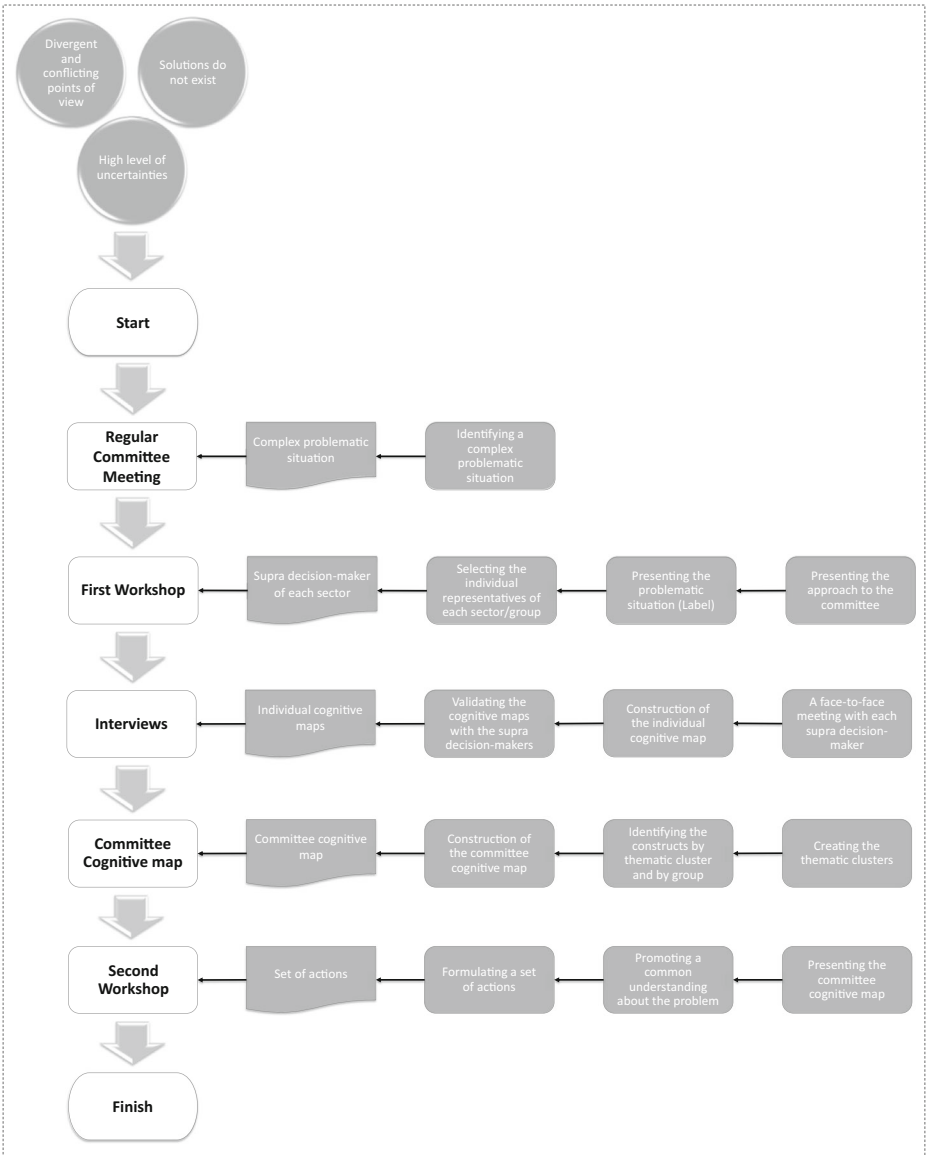


**Fig. 1** Flowchart of the proposed approach

approach; (iii) interviews with each group; (iv) construction of the committee cognitive map; and (v) second workshop for formulation of the set of actions.

The application of the approach requires a facilitator, who is responsible for conducting all activities. This actor plays a central role in the model and should be a non-member of the committee, as impartial as possible, but with ability to intervene whenever necessary, particularly, during the construction of cognitive maps. In order to promote a trust relationship during the application of the approach, all stages help to promote the impartiality of the facilitator.

### 3.1 Regular Committee Meeting

The model is appropriated for the cases in which the committee is discussing and trying to deliberate on a complex problem. Thus, the start point is to identify problem. To do this, the facilitator participates in regular meetings of the committee, observing the discussions in the group and trying to identify problems with following characteristics: high level of uncertainties on the proposed solutions or apparently no solutions exist for the problem; and/or divergent and conflicting points of view among individuals. The model will support the structuration of one complex problem at a time.

### 3.2 First Workshop

After the identification of complex problematic situation, the facilitator presents a workshop that is held at the following regular meeting of the committee. The goal of this workshop is to present the approach to the committee and to present the problem that is being structured by the model (the label) and to select the individuals who are representing each sector during the constructions of cognitive maps.

To select the participants, the members of the committee are grouped as follows: (i) government representatives; (ii) water resources users (representatives of agro-industrial, industrial, water supply companies, etc.); and (iii) civil society representatives. Each group chooses one member for its representation during the interviews for construction of the cognitive map of the group. The selected member is called "supra decision maker" and the groups can create their own rule to select their respective representative (for example, voting can be used), but it is important to observe if the individual has experience and expertise regarding the issue and if it is viable, in terms of time and cost, to perform the interview with him/her.

### 3.3 Interviews

At this time, each group is represented by its respective supra decision maker who was selected in the previous step. For the interviews, a face-to-face meeting should be held with each supra decision maker at a previously agreed place, according to the convenience of both facilitator and the supra decision maker. A total of three semi-structured interviews/discussions is performed (it is recommended to record the discussion).

During each interview, the facilitator must be able to engage the supra decision maker in discussing about the label in order to capture and record the perceptions that he/she has about the problematic situation. To avoid misinterpretation of an idea, facilitator must encourage him/her to give a statement that represents an idea opposite to the former.

As the supra decision maker speaks, the facilitator identifies the constructs i.e. an idea and its opposite idea and the logical dependence among them, according to the descriptive logic of the interviewed, using arrows to represent it with or without sign. The facilitator should use the software *Banxia Decision Explorer* in the elicitation of constructs and their relations to represent the construction of the cognitive map. Then, constructs should be categorized into: heads, strategic options, tails, implosions, explosions and dominants. At the end, the map is validated by the supra decision maker.

### 3.4 Construction of Committee Cognitive Map

At this step, the facilitator aggregates individuals' maps to construct the map of the committee that represents the perception of the group as a whole.

Firstly, the facilitator identifies themes that are being represented by the constructs in order to create thematic clusters; then, the facilitator identifies constructs by thematic cluster and by group (government, water resources users and civil society). After, the facilitator verifies if the maps of groups have constructs related with each other (representing similar ideas); these constructs must be converted into single map that encompasses the original ideas of all.

At this point, the committee map is constructed, observing the linking points among individual maps that are formed by the thematic clusters. Then, the facilitator will identify and analyze tails, heads, strategic options, implosions, explosions, dominants and potential feedback loops.

With the analysis of the committee map, the facilitator will gain a deeper understanding about the problem and relations that the issues have with each other, through the knowledge of the following information organized into the five types of constructs:

- key issues (strategic options) that are contributing to the global problem (head), indicating the nature of actions to mitigate the problem;
- implosions and explosion revealing multiple aspects of an issue, or even different point of views that the group may have about it, and the existence of connections that can exist among issues;
- dominant/major issues, if they exist;
- and, finally, the root causes (tails), indicating the course of actions to be implemented for mitigating the problem identified.

### 3.5 Second Workshop

The second workshop is the last activity of the structuration stage. It should be held at the following regular meeting of the committee and the main goal is to present the map. With the explanation of the map, the facilitator tries to promote a common understanding about the problem, solving potential conflicts that can emerge by showing that the map converge in the points of view and interests of the whole group, even when the ideas are presented in a different way.

With the analysis of strategic options, implosions, explosions, dominants and, specially, the analysis of the directions given by the root causes, the facilitator will support the group to formulate a set of actions for the mitigation of the problem at hand. It is important that all members of the committee accept the actions formulated by the group.

## 4 Application Results

An application of the approach was performed to support the committee of the Paraíba River watershed in northeastern Brazil (Fig. 2). The watershed has a drainage area of 20,071.83 km$^2$, covering 38% of the territory of Paraíba state, which corresponds to about 52% of its total

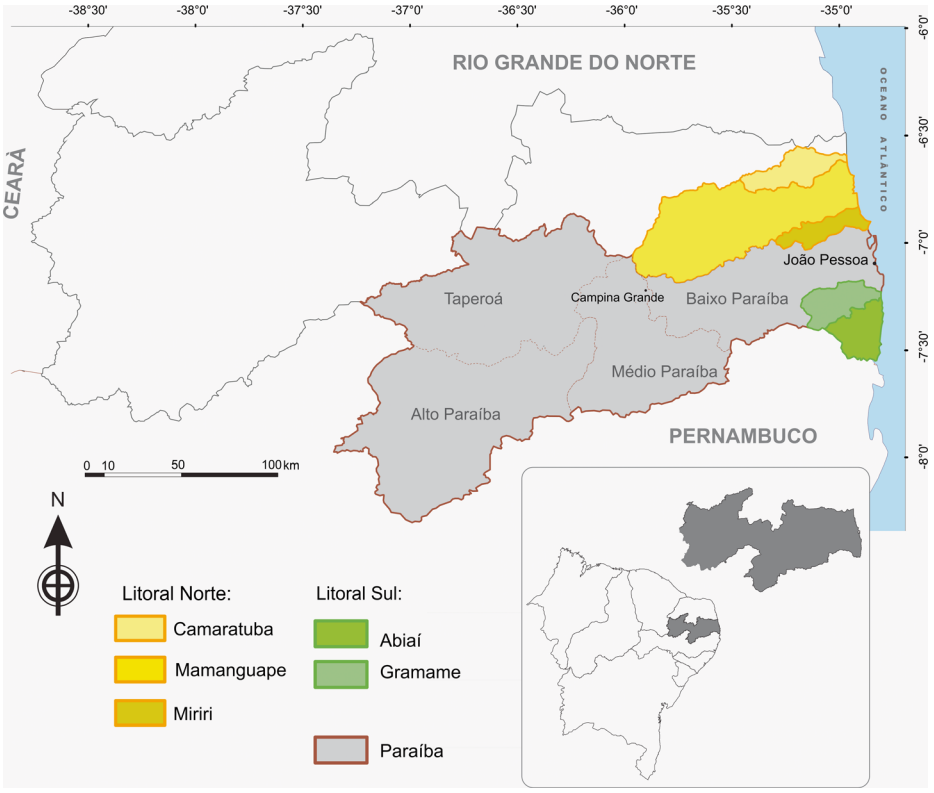


**Fig. 2** The Paraíba River watershed in northeastern Brazil

population (about 1,828,178 inhabitants), including the two biggest cities in the state: the capital João Pessoa and Campina Grande.

The recommendation is that the committee must be composed of sixty (60) members, as follows: civil society (30%); water resource users (40%); and government (30%) divided into Municipal Government (20%), State Government (7%) and Federal Government (3%); though, according to analysis of attendance lists performed by Ribeiro et al. (2016), the civil society achieved the rate of 40% of participation, followed by government and water resource users, with 31% and 29%, respectively. The average attendance per meeting was about 24.8 and some meetings were not held due to lack of quorum. It was also noted still a great effort and discussion is required on organizational structure of the committee.

Nevertheless, the committee of the Paraíba River watershed is one of the most active in Brazil, with regular meetings throughout the year, making it possible to apply the proposed model, as described below.

The authors of the paper acted as facilitators and the first regular meeting was held in August 2015, in Campina Grande, Paraíba, in which the structuration stage started. During this meeting, facilitators presented themselves to the members of the committee, gave them an overview about the model, and also identified the supra decision makers. At this point the model suffered a little modification - the model recommends that each group should chose its respective representative. Thus, this meeting encompassed two activities of the structuration

stage: regular committee meeting, for identification of a complex problematic situation; and first workshop for presentation of the approach and for selection of the supra decision makers.

The complex problematic situation emerged from a plan for mitigation of the degradation of the watershed that was proposed by the State Government and presented to the committee during this meeting. Therefore, the complex problematic situation to be structured is the degradation of the Paraíba River watershed. Regarding the supra decision makers, they are: a representative of local industries (water users); a government representative, who works at the Brazilian National Public Health Foundation; and a civil society representative, who works at a federal university.

The semi-structured interviews were held in workplace of the supra decision makers in João Pessoa and Campina Grande. The facilitator conducted the conversations using the following three questions: (i) "*what are the problems associated with the degradation of the basin?*"; (ii) "*how can we mitigate these problems?*"; and (iii) "*how are these problem's related with each other?*". Each decision maker had about 20 min to discuss these questions; for each given statement, the facilitator encouraged them to present an opposite idea to eliminate any subjectivity/ambiguity.

After that, the maps of each group was constructed and validated, followed by the construction of the aggregated map. According to the map, which contains sixty-nine constructs, the problem of degradation of the watershed can be explained by three key issues (Fig. 3): lack of adequate watershed management (construct 51); water scarcity within some areas of the basin (construct 2); and water resources pollution (construct 17).

Construct 25 ("stakeholders do not execute strategic planning") is an implosion and thus it summarizes the ideas expressed in the six constructs that are directly connected to it. Also, it is an explosion, revealing that this issue has influence over five other constructs. One of them is construct 51, which is also an implosion, with six other constructs leading to it. Therefore, all these constructs (a total of eighteen) are related to the issue "lack of adequate watershed management" that is immediately connected to the head (Fig. 3).

Two other implosions connected with each other are constructs 31 and 2. They compose a connection net containing ten constructs that is related with the central issue "water scarcity within some areas of the basin". Construct 17 is also an implosion with five constructs.

Therefore, almost 50% of the ideas expressed by the committee reveal multiple aspects of the issues management, scarcity and pollution. Among these constructs, construct 25 represents the centrality of the problematic situation, because of its dominance; it reveals an indication of the major issues that must be tackled to achieve the goal. In this case, the lack of strategic planning and thus management seems to be the dimension in which efforts must be concentrated for improving the situation of the basin.

By the analysis of the root causes, it is possible to identify the directions for improving the management of the basin and consequently mitigate the effects of its degradation. Table 1 presents the recommendations identified in the root causes and the related respective construct. Based on these recommendations, the set of actions are formulated.

Other recommendations can be inferred from the map regarding the water scarcity. Indeed, the group agrees that water scarcity, provoked by recurring drought in the region, contributes to the degradation of the basin; however, they also agree that the consequences of that could be significantly reduced if preventive actions regarding management aspects had been taken. Therefore, as indicated by the map, lack of adequate watershed management is currently the main issue of the committee.

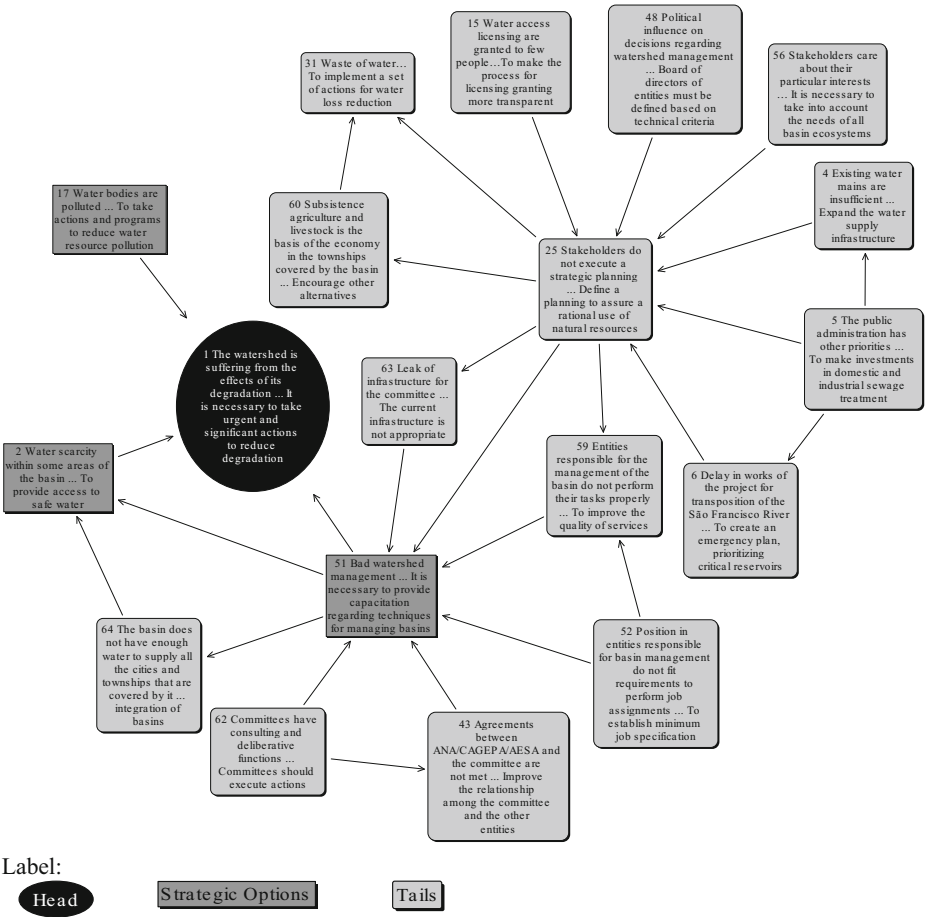


**Fig. 3** Strategic options and network formed by constructs 25 and 51

**Table 1** Recommendations regarding the management dimension

| Construct | Recommendations |
|---|---|
| 14 | Improve the process for water access licensing granting and inspection |
| 30 | Creating a benefit program for rural producers who protect ecosystems in the basin |
| 35 and 61 | Increase the number of employees in the entities responsible for the basin management |
| 38 | Finance the development of cheaper water desalination technologies |
| 40 | Implementation of a selective waste collection project in the townships covered by the basin |
| 41 | Capacity development regarding new technologies for water collection, storage and transportation |
| 42 | Allocation of budgeting for the management of the basin |
| 48 | The board of directors of the entities responsible for management of the basin must be defined based on technical criteria instead of political recommendation |
| 49 | Capacitation of the technical staff of the entities responsible for the integrated management of the basin |
| 57 | Public educational campaign to promote environmental awareness |
| 69 | Search for projects and laws that encourage townships to implement good environmental practices |

## 5 Conclusion

This study presents a group decision approach for supporting participatory water resources management and planning. The approach consists of the cognitive mapping of each interest group (civil society, government and private sector), represented by an individual of the group; then, these maps are aggregated to construct the map that represents the background of the group as a whole, converging all points of view and interests. By the analysis of this aggregated map, the group achieves a common understanding about a complex situation under investigation, helping the group to identify strategic alternatives for mitigation of the problem.

The approach is intended to support Brazilian watershed committee. It was refined as it was applied to the committee of the Paraíba River to structure a discussion about the degradation of the watershed, which inferred that lack of adequate watershed management is the major factor that contributed to the problem at hand. The application shows that the approach promotes a common understanding among the members of the committee, provides effective participation and finally assures that decisions made by the group are based on criteria in compliance with sustainability principles. All these aspects help to improve the efficiency of watershed committees and making the decision process more transparent.

One disadvantage of the model is related to the difficulties in describing how to construct the cognitive maps in SODA, which limits transferability of the model to be applied by an ordinary member of the committee; consequently, the model requires a decision analyst. On the other hand, the presence of a decision analyst assures the impartiality necessary to assure a relationship of trust among the decision makers and consequently to reduce conflicts amongst the different interest groups.

**Acknowledgements** The authors would like to acknowledge the committee of the Paraíba River watershed for its collaboration in applying the proposed model and the suggestions made by anonymous reviewers, which have contributed to make this a better final version. The Brazilian Research Council – CNPq, funded this research.

## References

Ackermann F (2012) Problem structuring methods 'in the Dock': Arguing the case for Soft OR. Eur J Oper Res 219(3):652–658

Ackermann F, Eden C (2001) SODA-Journey making and mapping in practice. In: Rosenhead J, Mingers J (eds) Rational Analysis for a Problematic World Revisited: Problem Structuring Methods for Complexity, Uncertainty and Conflict. John Wiley & Sons, New Jersey

Ackermann F, Eden C (2010) Strategic Options Development and Analysis. In: Reynolds M, Holwell S (eds) Systems Approaches to Managing Change: A Practical Guide. Springer, London, pp 135–190

Almeida S, Morais DC, Almeida AT (2014) Aggregation of stakeholder viewpoints using the value-focused thinking methodology in association with cognitive maps. Production 24(1):144–159

Brans JP, Vincke P (1985) A preference ranking organization method (The PROMETHEE method for multiple criteria decision-making). Manag Sci 31(6):647–656

Bryant J (1997) Requirements capture using SODA. Eur J Inf Syst 6(3):155–163

Caruzzo A, Belderrain MC, Fisch G, Manso DF (2015) The Mapping of Aerospace Meteorology in the Brazilian Space Program-Challenges and Opportunities for Rocket Launch. J Aerosp Technol Manag 7(1):7–18

Checkland P (2001) Soft Systems Methodology. In: Rosenhead J, Mingers J (eds) Rational Analysis for a Problematic World Revisited: Problem Structuring Methods for Complexity, Uncertainty and Conflict, 2nd edn. Wiley, New Jersey

Coelho AC, Labadie JW, Fontane DG (2012) Multicriteria decision support system for regionalization of integrated water resources management. Water Resour Manag 26(5):1325–1346

Dias R, Cabral AS, López B, Belderrain MCN (2016) The Use of Cognitive Maps for Requirements Elicitation in Product Development. J Aerosp Technol Manag 8(2):178–192
Eden C (2004) Analyzing cognitive maps to help structure issues or problems. Eur J Oper Res 159(3):673–686
Eden C, Ackermann F (2001) SODA-The Principle. In: Rosenhead J, Mingers J (eds) Rational Analysis for a Problematic World Revisited: Problem Structuring Methods for Complexity, Uncertainty and Conflict, 2nd edn. Wiley, New Jersey
Eden C, Ackermann F (2004) Cognitive mapping expert views for policy analysis in the public sector. Eur J Oper Res 152(3):615–630
Fontana ME, Morais DC (2013) Using Promethee V to Select Alternatives so as to Rehabilitate Water Supply Network with Detected Leaks. Water Resour Manag 27(11):4021–4037
Friend P (2001) The Strategic Choice Approach. In: Rosenhead J, Mingers J (eds) Rational Analysis for a Problematic World Revisited: Problem Structuring Methods for Complexity, Uncertainty and Conflict. Wiley, New Jersey
Georgiou I (2011) Cognitive Mapping and Strategic Options Development and Analysis (SODA). In: Cochran JJ, Cox LA Jr, Pinar K, Kharoufeh JP, Smith JC (eds) Wiley Encyclopedia of Operations Research and Management Science. Wiley, New Jersey
Hajkowicz S (2008) Supporting multi-stakeholder environmental decisions. J Environ Manag 88(4):607–614
Hjortsø CN (2004) Enhancing public participation in natural resource management using Soft OR—an application of strategic option development and analysis in tactical forest planning. Eur J Oper Res 152(3):667–683
Karjalainen TP, Rossi PM, Ala-aho P, Eskelinen R, Reinikainen K, Kløve B et al (2013) A decision analysis framework for stakeholder involvement and learning in groundwater management. Hydrol Earth Syst Sci 17: 5141–5153
Keeney RL (1996) Value-Focused Thinking: A Path to Creative Decision Making. Harvard University Press, Cambridge
Levino NA, Morais DC (2011) A proposal for structuring and evaluating problems for participatory decision making in sanitation context. IEEE International Conference on Systems, Man, and Cybernetics, Anchorage
Liao S-H (2008) Problem structuring methods in military command and control. Expert Syst Appl 35(3): 645–653
Liu S, Crossman ND, Nolan M, Ghirmay H (2013) Bringing ecosystem services into integrated water resources management. J Environ Manag 129:92–102
Manso DF, Suterio R, Belderrain MC (2015) Mapping out Sao Paulo state's disaster management system through. Gestão e Produção 22(1):4–16
Medeiros DFKL, Urtiga MM, Morais DC (2017) Integrative negotiation model to support water resources management. J Clean Prod 150:148–163
Mingers J, Rosenhead J (2001) Diverse unity: Looking inward and outward. In: Rosenhead J, Mingers J (eds) Rational Analysis for a Problematic World Revisited: Problem Structuring Methods for Complexity, Uncertainty and Conflict. Wiley, New Jersey
Mingers J, Rosenhead J (2004) Problem structuring methods in action. Eur J Oper Res 152(3):530–554
Morton A, Ackermann F, Belton V (2003) Technology-driven and model-driven approaches to group decision support. Focus, research philosophy, and key concepts. Eur J Inf Syst 12:110–126.
Mutikanga HE, Sharma SK, Vairavamoorthy K (2011) Multi-criteria Decision Analysis: A Strategic Planning Tool for Water Loss Management. Water Resour Manag 25:3947–3969
Oliveira MDNT, Ferreira FAF, Pérez-Bustamante Ilander GO (2017) Integrating cognitive mapping and MCDA for bankruptcy prediction in small- and medium-sized enterprises. J Oper Res Soc 68(9):985–997
Ribeiro MF, Ribeiro MM, Varanda MP (2016) Public participation for bulk water charge: Paraíba River Basin Committee (Brazil) and Alentejo Hydrographic Region Council (Portugal) cases study. RBRH 21 (4):777–788
Roozbahani A, Zahraie B, Tabesh M (2012) PROMETHEE with Precedence Order in the Criteria (PPOC) as a New Group Decision Making Aid: An Application in Urban Water Supply Management. Water Resour Manag 26(12):3581–3599
Rouwette E, Bastings I, Blokker H (2011) A Comparison of Group Model Building and Strategic Options Development and Analysis. Group Decis Negot 20(6):781–803
Silva Filho JL, Fontana ME, Morais DC (2014) Strategic Options Development and Analysis to identify criteria to evaluate segmentation problems of a water distribution network. IEEE International Conference on Systems, Man, and Cybernetics, San Diego
Silva VB, Morais DC, Almeida AT (2010) A Multicriteria Group Decision Model to Support Watershed Committees in Brazil. Water Resour Manag 24(14):4075–4091
Simpson P, Beeby M (1992) Facilitating Public Sector Organisational Culture Change through the Process of Transformational Leadership. Manag Res News 15(5/6):39–40