Real world decision-aiding: a case of participatory water management

Katherine Anne Daniell, Chabane Mazri, Alexis Tsoukiàs[1]

Abstract In this chapter we present a proposal for decision-aiding in a participatory situation in the real world may constitute, in particular for water management. We first outline the context in which these decision-aiding processes take place: "messy" inter-organizational settings. We then present some of the available decision-aiding theories and models that could be used, and adapt one of these, a decision-aiding process model based on Tsoukiàs (2007), for this inter-organizational context. We next highlight how the model was used in a research intervention for the creation of the Lower Hawkesbury Estuary Management Plan in Australia. We demonstrate how this model significantly aided the structuring of the decision-aiding process and promoted insights on its usefulness and validity. We also provide an *ex-post* operational validation of the Mazri (2007) decision-aiding model for participatory structure design. From the real-world intervention case we also justify our claims that: 1) we need decision-aiding methodologies to improve inter-organizational decision-making for water management, as well as theoretical models and problem structuring methods that can form useful parts of these methodologies; and 2) we need negotiation skills, amongst others, for putting the methodologies in place in the real world.

1 Introduction

Decision-making is becoming increasingly complex in many sectors. This is due to overlapping legislative requirements, multiple decision-makers and managers, competing interests, unequally distributed resources and social and environmental impacts, as well as uncertainties about the future in a more connected and rapidly changing world. This is certainly the situation for water management in many regions of the world, where decision-makers are faced with increasing levels of uncertainty, complexity and conflict. In such contexts, the decision-making process over the selection and implementation of water management strategies becomes a major challenge. In order to ensure the sustainable development of water resources and their dependent societies and environments, there is an increasingly recognized need for the development of improved approaches to aid inter-organizational or multi-stakeholder decision-making in the water sector.

[1] Katherine Anne Daniell, Australian National University, katherine.daniell@anu.edu.au
Chabane Mazri, INERIS, Chabane.MAZRI@ineris.fr
Alexis Tsoukiàs, LAMSADE-CNRS, Alexis.Tsoukias@lamsade.dauphine.fr

In this chapter, we first outline the challenges real-world complexity presents in the water sector, followed by an introduction to the concept of decision-aiding and its relevance to participatory, inter-organizational water management. Decision-aiding models that could be used in this context are then outlined, in particular a participatory structure design and a decision-aiding process model. We then present a real case in Australia, where a theoretical model underlay elements of the participatory workshop series used in the creation of the Lower Hawkesbury Estuary Management Plan in New South Wales. We thus, highlight the usefulness of decision-aiding models to drive the success of participatory water management planning. Challenges encountered are discussed, including the case when multiple analysts and decision-makers must collectively design a decision-aiding process.

2 Participation in the real world

To introduce our example case of decision-aiding in the real world, we will first highlight the typical complexities encountered in the participatory water management domain. We then briefly introduce some of the existing theory and practice of aiding decision-making in inter-organizational contexts, as well as the levels of participation of different organizations or stakeholders who take part in decision-aiding processes.

2.1 Complexities in water management

Water management faces many challenges to overcome as the complexity and inter-relatedness of problems increases. Socially based water management disputes commonly result from differences in stakeholders' values and viewpoints, interests on how water should be used, and power struggles over scarce water resources. Highly value-charged debates are often sparked over questions of whether water is equitably distributed between people and geographical areas or is of sufficient quality for human and environmental needs. Since the 1970s, protests and social activism over water management projects, such as dam construction, have become more widespread (Hutton and Connors 1999). Local issues can now quickly create international level protests thanks to rapid information transfers enabled via new technologies such as the Internet and global media networks. Human rights issues were for example the focus of international protests over the displacement of the estimated 1.3-1.9 million people for the Three Gorges Dam on China's Yangtze River (Gleick et al. 2006). The growing interconnectedness of world systems means that almost all local human activities can have global impacts. This may be by economic processes, such as trade, or via societal changes at physical, cultural, environmental or individual human levels, which include changing beliefs, values, views, relations and practices.

Nowadays, water management typically requires representatives at multiple levels of governance to decide how water should or can be used and shared between a variety of stakeholders and the environment under conditions of major uncertainty. Such uncertainties and areas of potentially rapid change include: cli-

matic conditions and natural hazards such as floods, droughts, volcanic eruptions, disease outbreaks, earthquakes, tsunamis and cyclones; technology and scientific innovation; political regimes and priorities; the economic climate; and human behavior and cultural imperatives. A major challenge is to aid water management in this increasingly populated, globalized, environmentally degraded and inequitable world with unprecedented levels of complexity, uncertainty and conflict.

This challenge is made more difficult due to the fact that water management processes are highly distributed activities occurring at a multitude of spatial, temporal and institutional scales. Each local area around the world has a variety of different water-related issues in need of management, and at each larger scale there are numerous planning and management groups responsible for overseeing the coherence of these local efforts to ensure that more sustainable overall directions are pursued at their own level. This has resulted in many layers of water management practices which are all interrelated and attempt to deal with different stakeholder groups and their issues, needs, values, interests, representations, resources and actions in dynamic, complex situations; often with limited success.

In light of this increasing water management complexity, we consider that one of the most pressing needs is to *develop and implement adapted methods of aiding inter-organizational decision-making processes for improved water management*.

2.2 Aiding inter-organizational decision-making

Decision-aiding in the inter-organizational context focuses on providing a "decision analyst" or analysis steering group with methodological aids that allow facilitation of a group of representatives from a range of organizations or stakeholder groups to structure and exchange views. These exchanges may span focal areas ranging from problem formulation and objective identification to final recommendations or "choices". This process can be considered to occur in an "interaction space" (Ostanello and Tsoukiàs 1993) or a "collaborative space" (Digenti 1999), where the collective construction of the participants' representations of the problem can be regarded as a "model", "meta-object" (Tsoukiàs 2007) or "intermediary object" (Vinck and Jeantet 1995), which can form the basis for further collective discussion and decision-making. Interactions between the various process participants are governed by rules that may only exist within the "interaction space". Related to this description, Mazri (2007) defines an *interaction space* as: "*a formal or informal structure that is governed by a number of rules and is aimed at providing a field of interaction to a finite set of actors.*"

In inter-organizational groups with representatives participating in the interaction space, there are certain context specificities which need to be considered by analysts developing decision-aiding approaches. For example, unlike in groups that share the same organizational background and accountability structures, there will be outside factors, interests or rules which will affect the ability of each participant to agree on decisions. Participants may only have limited power to enter into commitments on behalf of their organizations, making such a working group "multi-accountable", unlike a traditional "team-like" group (Friend 1993). In this

context, we consider that the "interaction space" of the decision processes will not be limited to just a working group which meets, but rather expanded to include the external interactions and negotiations that are likely to occur in and between each participating organization at different managerial and government administration levels. This expanded interaction space for inter-organizational, "multi-accountable" groups is represented in Fig. 9.1. Unlike the central interaction space, it may not have easily identifiable finite bounds.

We stress that our definition of *organization* in "inter-organizational" groups is taken in the broadest possible manner; as a group, association, business, institution, government or any ensemble of two or more people who share at least one common characteristic, interest, vision or goal. In Fig. 9.1, representatives from the same organization are represented with the same shading. Double headed arrows represent interactions that may occur outside the central interaction space and that have an impact on the shared representations produced.

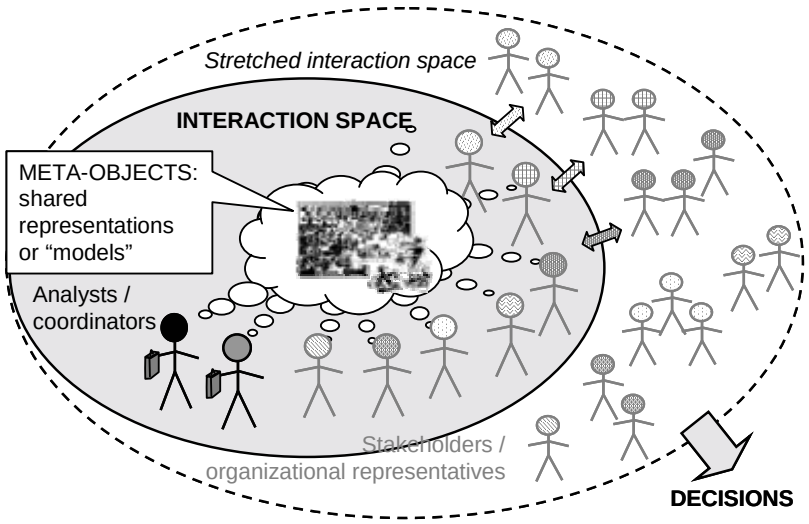

Fig. 9.1 Decision-aiding for "multi-accountable" groups in a stretched interaction space.

The decision-aiding processes used for multi-accountable groups must be applicable to these more complex environments. In particular, where those participating with the analyst in the central interaction space rely upon others from the stretched interaction space to make the final decisions, Alexander's (1993) theory of "interorganizational coordination" considers a similar setup where the participants working in the central interaction space are labeled as an "inter-organizational group" and the whole stretched interaction space, including the central zone, constitutes the "inter-organizational network". We further consider that analysts in our interaction space use a variety of methods to marshal the different skills and knowledge required for working with a diverse group of organiza-

tional representatives to create their common representations. This analyst-led coordination process is represented by the "coordination structures" outlined in Alexander's (1993) framework.

In such complex organizational situations, Akkermans (2001) suggests that in traditional organizational theory from the management sciences, focusing on command and centralized hierarchical control is of limited value for analysts involved in the coordination of decision-aiding processes, because of the lack of a formal single locus of authority. Rather, the networks' decisions and collective actions are driven by the power and influence of the individual representatives and their supporting organizations, through means such as communication, persuasion and consensus building.

In this section we have so far concentrated on outlining the structure in which inter-organizational decision-aiding can occur. We also want to understand what dynamics may take place in an inter-organizational decision-making process. On this topic, Ostanello and Tsoukiàs (1993) provide a descriptive model of such a process, which outlines a number of characteristic "states", based on the ideas of MacKenzie's (1986) "process laws", that could be observed in the evolution of the interaction space. In this model, the process state is defined in terms of: the participating "actors"; "objects" (the concerns or stakes of the actors); "resources" that the actors are willing to commit to their objects of interest; and the "relations" between these elements (Ostanello and Tsoukiàs 1993). Such a model, even if simplified to just a few theoretically important variables, can provide a useful basis for understanding inter-organizational decision dynamics and therefore provides a conceptual framework for the development of a decision-aiding approach to guide the evolution of the interaction space in a favorable direction.

2.3 Levels of participation

We now turn our attention to the question of what "levels" of participation these organizational representatives may have in the central interaction space. To explain what we mean by "levels" of participation in a decision-making process, we give the following examples, to which we hope most readers will be able to relate. A woman comes home from work and to her husband:

1) announces that they are to go out together to dinner tonight
2) announces that she wants to go out to dinner and asks what he thinks about the idea
3) asks her husband if he prefers going out for dinner or to the theater
4) asks, "What shall we do tonight?"

In other words, the person asking the questions can choose how much to include someone else in a decision-making process. In our inter-organizational situation it will typically be the coordinators or analysts who, in interaction with the decision maker(s), attempt to define the participation levels which best suit each stakeholder. This should occur according to their expectations and potential to contribute to creating the best possible "common" representation. Mirroring the levels in our anecdote, Mazri (2007) proposes a four-step classification for deci-

sion-aiding processes for risk management where: Level 0 is “information”; Level 1 is “invited response to information”; Level 2 is “consultation”; and Level 3 is “implication in decision-making”. These levels are placed on a grid for purposes of an analyst’s choice of participation for each potential organizational representative, based on his or her adequacy of resources and stakes for treating different objects of debate in a decision-aiding process. The concept of “adequacy” of these stakes and resources relates to the level of relevance or correspondence of these actors’ attributes to the object of debate requiring a decision. For example, an actor having a high adequacy of resources to understand an object of debate but is unlikely to be impacted by the decision (few stakes in it), could just be consulted (Level 2) to obtain those knowledge resources. This grid is represented in Fig. 9.2. The idea of “objects of debate” will be further discussed in this chapter.

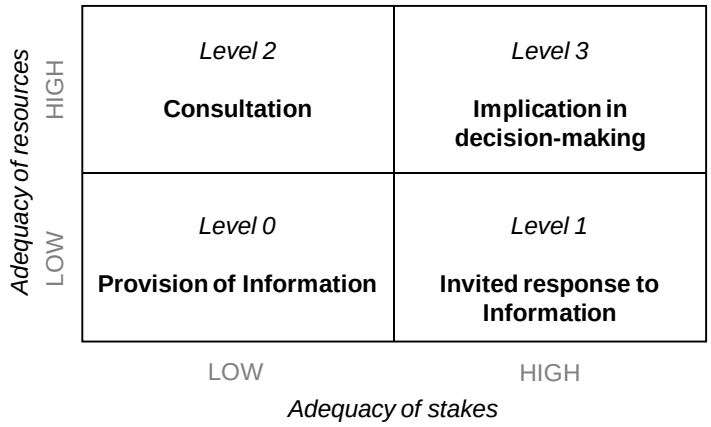

Fig. 9.2 Defining levels of participation in decision-making processes.

This classification system of participation levels is but one of many. However, it is differentiated from a number of the traditional power-based or empowerment-based classifications, due to consideration of both the “stakes” and “resources” dimensions. Most power-based classifications were developed in an attempt to give citizens more control over government-run decision-making processes that affect them (e.g., Arnstein’s (1969) ladder of public participation or Mostert’s (2003a, b) classifications for water planning and management). Empowerment-based classifications were developed in a slightly different light to promote maximized enlightened collective action and social learning (e.g. Rocha, 1997, or Cornwell, 1996). We see Mazri’s (2007) classification as a useful platform to start our consideration of the design of theoretically-based decision-aiding processes, although we also stress that many later choices of specific methods used in the interaction space to promote the creation of common representations could also be oriented to enhance social learning or multi-organizational collective action and empowerment. It is also important to consider here that this classification should

not be used as a rigid guideline free of the decision-context. Rather, it should be used as a soft model that helps decision makers and analysts to define the best participatory structure considering the context (including its constraints) and stakeholders specificities (Mazri 2007). More precisely, the distinction between low and high levels of resources or stakes is largely subjective and should reflect the openness of the decision maker(s) to dialog. We also note that decision makers can easily increase some of the stakeholders' knowledge resources by providing training sessions related to the issues in need of decisions.

We conclude this discussion with two remarks:

1. Participatory decision structures are chosen to be such. It is not always the case that it is convenient to have carefully developed structures mapped to individual stakeholders since they can be expensive to develop, possibly ineffective and their outcomes potentially uncertain.

2. Establishing a participatory decision making structure is itself often a participatory decision-making process, which occurs between the analyst and one or more decision-makers and sometimes organizational representatives, see **Bayley** for further information.

3 Theoretical models and methods for decision-aiding

Theoretical models for decision-aiding have been studied in a number of disciplines, including operational research or management science, law and psychotherapy (Brown 1989, Capurso and Tsoukiàs 2003, Tsoukiàs 2008). In this section we highlight two models from the field of operational research decision-aiding. We will start with a model of how to design a participatory process structure and move on to a model for eliciting process content from the participants. Currently available participatory methods designed to aid such elicitation will be briefly introduced, followed by a critique and methods for working with inter-organizational or multi-accountable groups.

3.1 Participatory structure model

Before thinking about potential methods and how to conduct a participatory decision-aiding process, we shall address some issues of decision-aiding process initiation and design. When commencing an inter-organizational decision-aiding exercise, it is likely that there will be some preliminary interaction between the "decision analyst" and one or more of the organizational representatives. During this preliminary interaction, an agreement may be made to help these organizations structure and manage a particular issue under certain rules of engagement (Avenier et al. 1999). Once an agreement has been created, a general process design, including the "participatory structure" under which the exchanges in the interaction space are to take place (Mazri 2007), needs to be developed. In this process design phase, the decision analyst's capacity to engage the participants (Creighton 2005) needs to be legitimated. Representatives from different organizations who are considered to have interests in certain objects of debate related to

the problem situation can then be invited to participate in the decision-aiding process through the construction of the meta-objects or models, as denoted in Fig. 9.1. A model developed by Mazri (2007) for the design of participatory structures, stemming from the field of OR, is presented in Fig. 9.3. .

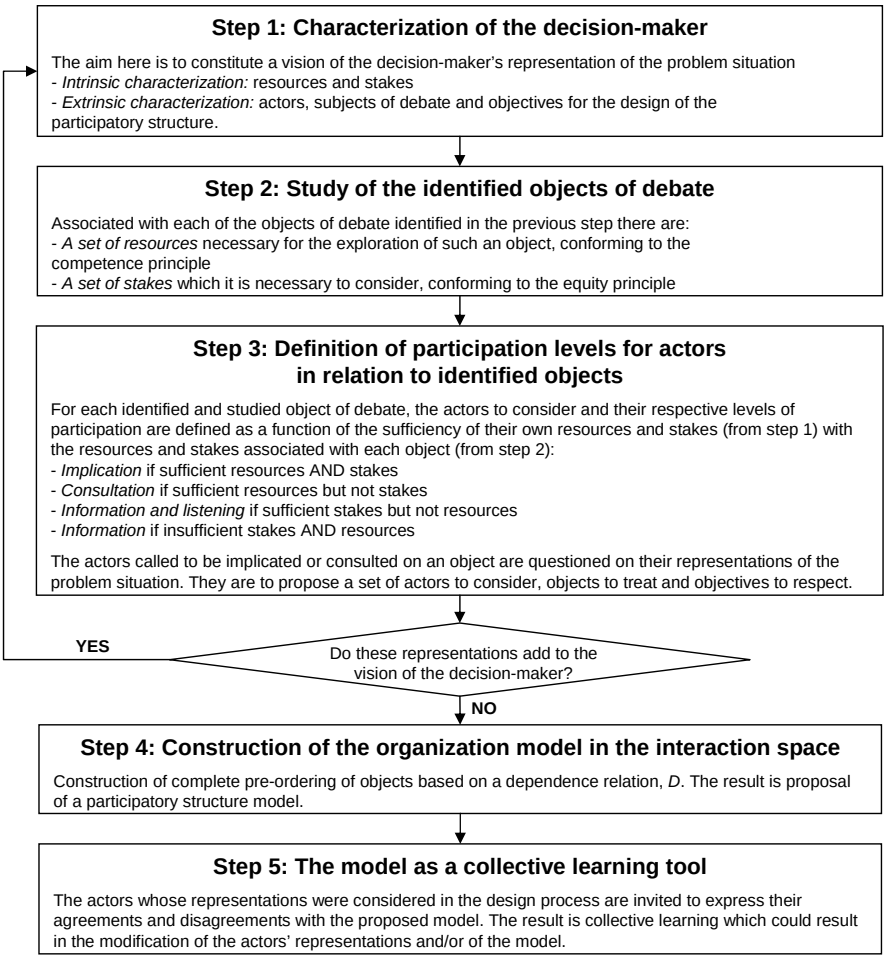

Fig. 9.3 Descriptive model of the participatory structure design process (Mazri 2007).

Note first that this is not a model for the autocratic design of a participatory structure, but rather a model for the participatory process of design of the participatory structure between the analyst, decision-maker and potentially a number of other actors. The model starts with two steps to characterize the decision-maker and study a number of objects of debate. For the characterizations, "intrinsic" refers to basic elements that the decision-maker or actors use to build a worldview including: "stakes" which may be *concerns or interests* in a wide range of contex-

tual elements (i.e. social, environmental, economic); and "resources" belonging to the actor. These resources include: *a set of knowledge bodies* (scientific, practical, contextual, etc.) that can be employed to understand and study the problem situation; *value systems* considered legitimate for the problem situation under study and that can be used to influence the outcomes of a participatory process; and *attributes that confer powers of influence* such as judicial attributes including legal responsibility, economic attributes including financial resources, and social attributes including respect, charisma and confidence (Mazri 2007). "Extrinsic" characteristics are those elements which can be used to describe the representation of the problem situation in which the actor is evolving, in this case relative to the creation of a participatory structure: who is relevant to the problem context that the actor thinks should be involved in the creation of the participatory structure and why; what are the most critical elements of interest that should become objects of debate considered by future participants in a participatory process; and for which objectives, such as a legitimate decision-making forum, conflict resolution or advisory process, should the participatory structure be designed (Mazri 2007).

Another point in Fig 9.3 that requires further explanation is the definition of the principles of "competence" and "equity" referred to in Step 2. Firstly, the principle of "competence" of the actors stems from the work of Habermas (1984) where it is used to describe a set of possibilities and talents of an actor, which is also similar to the set of deliberative rules suggested by Webler (1995) and Mazri (2007). Similarly, the principle of equity is based on the work of Habermas (1984) and that reformulated by Webler (1995), and is to be assured when an "ideal speech situation" is maintained in which the set of participating actors have equal chances to: formulate and explain their declarations; present and defend their positions relative to the four validity constraints of comprehensibility, truth in the scientific sense, normative rightness, and sincerity (truthfulness); contest validity claims of other participants; and influence the final modes of validation or decision-making rules and, hence, selection of final recommendations (Webler 1995, Mazri 2007).

The last point of note relates to the creation of the organizational model in Step 4, where the dependence relations between each two of identified objects of interest (for which levels of participation based on Fig. 9.2 are defined in Step 3) in the participatory structure are developed. Mazri (2007) defines three types of dependence relations between the objects: dependence (uni-directional relation); interdependence (bi-directional relation); and independence (no relation). From these dependencies, a logical series of objects to be treated in the participatory structure can be developed, similar to a work flow diagram where the critical path can be established to aid additional implementation planning.

Of particular interest in this formalized participatory structure model is the iterative nature of the process and the search for continual improvement and social learning as the process progresses. Mazri (2007) notes that there may also be other types of feedback in between different steps of the process, and not only around the represented loop, which would aid to encourage further reflexivity of, and social learning between, the actors. Validity of the model is based on adherence to

the ideals of competence, equity, efficiency (the structure permits efficient use of resources) and legitimacy (the structure is accepted and legitimized in the context of decision-aiding that it has been designed for) (Mazri, 2007). From this participatory structure model, we now move on to outline a decision-aiding process model that could be used for examining each of its identified objects of debate.

3.2 Decision-aiding process model

In operational research, decision-aiding (process) models do not just include guideline-type models, but also models based on formal and abstract language. For example, the model of Tsoukiàs (2007) defines a number of cognitive artifacts which are to be generated through the phases of the decision process. Each cognitive artifact is composed of a number of sets of elements, which can be represented using set theory. The decision-aiding process model producing these artifacts is shown in Fig. 9.4. There may be iteration between the building of these cognitive artifacts and feedback to previous phases to update them, which is represented by the dotted lines in Fig 9.4.

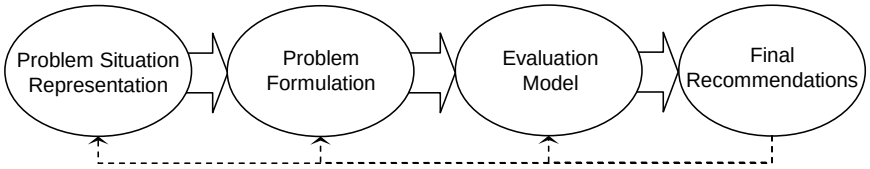

Fig. Four-stage decision-aiding process model. Derived from: Tsoukiàs (2007).

Following Tsoukiàs (2007), each of the phases or "meta-objects" outlined in the model can be characterized by a number of elements. These are to be elicited or developed through the process as follows:

- Problem Situation – definition of: a set of actors (i.e. stakeholders, experts); a set of objects (i.e. concerns, interests or stakes of the actors); and a set of resources (i.e. factors linked to the actors and objects);
- Problem Formulation – definition of: a problem statement (i.e. the area of a problem situation which requires decisions); a set of potential actions (that actors may take relative to the problem statements); and a set of points of view (that the actors may use to observe, evaluate and compare the actions);
- Evaluation Model – definition of: a set of alternatives (i.e. action sets or scenarios) to be evaluated; a set of dimensions, attributes, or indicators and their corresponding scales under which the alternatives will be described and measured; a set of preference criteria for alternative evaluation; an uncertainty structure; and a set of operators which will allow the synthesis and manipulation of all of the above information to aid decision-making.

- Final Recommendation – definition of a chosen decision related to the problem statement with corresponding validity/legitimacy analyses (i.e. sensitivity or robustness analyses and process and content evaluations).

Using "formal" and "abstract" models as a basis for decision-aiding provides a number of benefits over other types of support such as guidelines in certain problem situations, including that these models can: be used to reduce the ambiguity that is structured in human communication; and are generalized theoretical constructs which are independent of the decision-aiding context (Tsoukiàs 2007).

3.3 Criticism and extension

Although these two models aid our understanding of how a participatory structure and a decision-aiding process could be more effectively designed, both may require some innovation in order to be applied in the real world inter-organizational context of the water sector described in the first section.

Firstly, Mazri's (2007) participatory structure model only considers that there is one decision-maker who compares his or her views to those of other actors in order to enrich his or her own views. Although this main decision-maker is common in the French administrative context of local planning and risk management (the "Préfet" has the ultimate decision authority), in other inter-organizational cases there is likely to be more than one ultimate decision-maker. For example, accepting transboundary water plans will likely require the decisions of a number of administrations, with some decision-makers being able to block others. In such a case, Mazri's model would likely have to be applied either numerous times with these different decision-makers to obtain their views on the participatory structure and then come to a compromise, or else apply within the group with a common vision of a participatory structure being formed through dialogue.

A similar critique can be made of Tsoukiàs' (2007) model if is to be used in an inter-organizational context. The model was originally developed for a simple analyst-client relationship rather than for the intra- or inter-organizational context. The adaptations to the model required for it to be relevant to the inter-organizational context would include defining multiple problem statements. For example, one problem statement could stem from each of the actors associated with or having an interest in the decision-making process. This change would then have follow-on effects to the elicitation of other elements through the model, including that a set of final recommendations would also be required.

More generally speaking, the above models fail to appropriately consider the specificities of multi-accountable groups. There is empirical evidence (see Mingers and Rosenhead 2004) that problem situations exist where a "multi-client" perspective can be taken. We mean this in the sense that the decision-aiding process refers to multiple actors who share power over decision-making, who do not necessary share any cognitive artifacts that have been developed to improve the problem situation, and who require the presence of an analyst, often in the form of a facilitator. Moreover, to the concept of "analyst" we may associate a team of indi-

viduals who (partially) reflect the stakes within the interaction space and the interests of the different stakeholders.

Therefore, we may also extend the model based on the inter-organizational context outlined in Fig. 9.1 to further specify the set of actors into:

- a subset of "core participants", who interact in the "interaction space";
- a subset of "associated stakeholders", who may be either directly related to the core participants through organizational or personal affiliation, or unrelated to the core participants and where their stake in the problem situation may be known or unknown to core participants; and
- a subset of "project team members", such as the "analysts" who are responsible for facilitating, organizing and managing the decision-aiding process, including any required external analysis outside the interaction space. Members of this set may also either be "core participants" or "associated stakeholders" at any point in the decision-aiding process.

We consider that throughout the decision-aiding process a number of feedback loops or iterations between the four meta-objects (see Fig. 9.4) are likely to occur, in particular to allow formal or informal input from the "associated stakeholders" who will eventually have some authority over accepting and making decisions based on the final recommendations.

As these models are constituted of formal and abstract constructs, how exactly they are to be used must be determined by the analysts taking part in the design and implementation of the decision-aiding process. A decision-aiding process in an inter-organizational context and the use of the decision-aiding model are likely to be part of a larger planning and management process, the context of which must be taken into account by the analysts. Under these constraints there is then a need for method choice or design to obtain the formal elements of the model and use them in a coherent manner that can be tested for their validity and legitimacy (Landry et al. 1983, Landry et al. 1996).

In general, there may be a variety of possible methods that would be acceptable for allowing the process of modeling and exchanging views on certain elements of the meta-objects, but which ones are to be chosen or designed will likely have to be negotiated between the project team members (analysts, coordinators and potentially some core participants or associated stakeholders).

A range of methods, such as mapping exercises, individual reflection and collective discussion and analysis, may be used to elicit the set elements and relations between them within the problem situation, dependent on the context and the project team's capacities and preferences and the stakeholders' needs. Specific methods likely to be useful for inter-organizational settings include those from OR research and practice known as "problem structuring methods", as outlined in **Carreras and Franco**.

Specific methods used in decision-aiding processes to respond to increasing complexity, including in the water sector, include participatory modeling, also known as "shared vision modeling" (Palmer et al. 1993), "group model building"

(Vennix 1996) or "mediated modeling" (van den Belt 2004), where the analyst takes the role of the facilitator or modeler to attempt to understand and synthesize collective knowledge. Different types of models, including cognitive or causal maps, may be developed in the problem situation and formulation phases, and then simulation models or multi-criteria matrices may be used in the evaluation model stage. Some of these processes have the potential to move closer to being processes of "rationalization" in the sense of Habermas and his communicative action theory (Habermas 1984). Such processes of co-construction theoretically occur in an "ideal speech situation" where the confrontation of different stakeholders' rationalities through deliberative discourse and interaction can occur as a means of coming to commonly legitimized decisions (Habermas 1996). To what extent this model of communicative action can be validated in practice through these processes and how participatory modeling can be best organized as a collective decision-aiding process is still in need of investigation.

The problem of decision-aiding in the current and future world water sector therefore requires further research, especially on how decisions can be better aided. It is increasingly difficult to legitimate the use of some OR decision-aiding tools, such as optimization or hydrological models on a purely normative basis, as was traditionally possible in technocratic societies where the place of the "expert" was not challenged (Fischer 1990). This is largely due to the realization that there are multiple human rationalities which are difficult to take into account in decision-aiding processes without adapted consultative or participatory methods. These processes would include stakeholder communities, encompassing citizens or "the public", officials or decision-makers (policy makers and managers) and experts (Thomas 2004). If the use of such OR tools or models can be constructively legitimized through such participatory modeling processes – in other words, the stakeholders take ownership of the problem, its formulation, the models developed and used, and the recommendations – such models may still prove valuable in the quest to manage and find sufficing and collectively legitimated solutions to complex water management challenges.

Considering this discussion we make the following claims that will be investigated through the case study presented in the next section:

1) we need a decision-aiding methodology to improve inter-organizational decision-making for water management, as well as theoretical models and problem structuring methods that can form a useful part of this methodology; and
2) we need negotiation skills, amongst others, for putting the methodology in place in the real world.

4 Intervention case: regional estuarine management in Australia

The intervention case presented here describes the creation of the Lower Hawkesbury Estuary Management Plan (LHEMP). We first give some back-

ground to the context of estuarine management in Australia, before treating the specifics of the decision-aiding process.

The Lower Hawkesbury River and its estuary are located on the northern fringe of Sydney Metropolitan Area, separating Sydney from the Central Coast Region of New South Wales in Australia. The estuarine region has a warm temperate climate (Miller and van Senden 2003) and contains a large percentage of bushland, much of which lies in National Parks adjacent to the waters and is currently protected from land development. The region has many areas of intense scenic beauty and harbours many important ecological, economic, cultural and social values. The estuary supports a few small foreshore settlements which provide the oyster, prawn trawling, fishing and tourism industries with necessary infrastructure and access to their activities. Most of the urban, industrial and agricultural land uses are located further up the estuary's tributary creeks.

The region is currently attempting to cope with a number of important pressures including: high population growth, estimated to be a 15% increase over the last ten years to 2006 and holiday season population influxes; pollution from a variety of sources, including runoff from urban and agricultural areas, discharges from sewerage treatment plants (STPs), boat discharges, toxic substances found in boat anti-fouling paints and slipway scrapings, construction and dredging activities; pest, disease and aquatic weed infestations and outbreaks; unnatural flow patterns, for example due to STP inflows and water extraction; controlled burning and bushfires; and intensive recreational use (Forrest. and Howard 2004, HNCMA 2005, HSC 2006b, BMT WBM 2008).

Recent major issues for estuarine management have included the 2004 outbreak of QX disease in the Sydney Rock Oyster population, causing high mortality rates and substantial economic losses (DPI 2006); the outbreaks and growth of the aquatic weed, *Caulerpa Taxifolia,* since 2000 (Kimmerikong 2005); toxic algal blooms which pose threats to a number of aquatic organisms, the oyster industry and recreational water users; and contentious issues related to estuarine inflow qualities and quantities from STPs, on-site sewerage treatment systems and stormwater runoff. Future management is likely to be impacted by similar issues and the effects exacerbated by climate change mechanisms (CSIRO 2007).

Current estuarine management practice in the Lower Hawkesbury is subject to a large variety of policies and statutory controls. Policies created at the international level or at the Australian Government level are typically translated into State level policy and legislation. One of the main exceptions is the new *Water Act 2007* which may be enforced at the Federal level. However, its relevance to the estuary is likely to be limited to complying with the new provisions related to the Bureau of Meteorology's access to water information. Therefore, the majority of estuarine management considerations fall under at least 12 relevant pieces of State Government legislation and a range of policies, including State Environmental Planning Policies (SEPPs), as well as falling under Local Government Development Control Plans (DCPs) and Local Environment Plans (LEPs). Other policies and plans that are relevant to this estuary's management include the Hawkesbury-

Nepean Draft Catchment Action Plan 2006-2015 sets the direction for investment priorities. Further information on relevant legislation and policies applicable to the Lower Hawkesbury Estuary is available in BMT WBM (2008).

Related to the multiplicity of regulations, laws and policies which have a bearing on estuary management, there are also a large number of actors responsible for ensuring compliance with these instruments, including several Local Governments, State Government Departments and the Hawkesbury-Nepean Catchment Management Authority. Furthermore, other regional stakeholders and estuarine users such as industry groups, water agencies, recreational associations and users also play a significant role in estuary management through their own actions or by their work in local Estuary Management Committees which develop sub-regional estuary management plans in areas under Local Government control. However, the efficacy of overall management in the Lower Hawkesbury Estuary is thought to be currently limited due to policy fragmentation and a lack of coordination of management actions (Kimmerikong 2005). The region is therefore in need of an integrated multi-institutional, multi-stakeholder agreed and adopted plan for action in order to ensure a more sustainable future for the socio-ecological estuarine system under current and new challenges.

In light of these challenges, the participatory decision-aiding process for the plan creation was largely driven by the Hornsby Shire Council, one of the local governments in the planning zone and supported by researchers and consultants. The participatory process stages, including three interactive workshops, were adapted to adhere to the Australian and New Zealand Standard for Risk Management (AS/NZS 4360:2004), and an external scientific and legislative review was carried out by consultants (BMT WBM and SJB Planning) in the project team. A range of stakeholders from state and local governments, the water and sanitation authority, local industries, community associations and residents took part in the process stages of: “initial context establishment”, including the definition of estuarine values, issues and current management practices; “risk assessment” based on the stakeholder defined values (assets) and issues (risks); and “strategy formulation” to treat the prioritized risks as input to the estuary management action (or “risk response”) plan. Further risk assessment of the actions defined from the strategy formulation and external review was completed by the consultants in collaboration with the local government representatives driving the process. The draft management plan (BMT WBM 2008) was put out to public exhibition for further comments and the final revised plan has been recently accepted by both local governments in the region approximately two and a half years after the commencement of the participatory process. For this chapter, we will concentrate our case definition section on how the decision-aiding process based on the Tsoukiàs (2007) model was initiated and the decision-aiding methodology collectively designed. In-depth information and evaluation of the implemented participatory process may be found in the workshop reports (Daniell 2007a, b).

4.1 Decision-aiding case definition

Having a legitimate role as an analyst or coordinator of a real-life inter-organizational decision-making process appears crucial to being able to introduce decision-aiding theory and methods into the process. This was a key concern of the first author (who we will call "the researcher" in this section) when trying to find an appropriate intervention case for her research on the operationalization of these models and methods. In the LHEMP process, the researcher's legitimization was first constructed through her inclusion in the public tender written by the Local Government's estuary manager to contract a project manager for the plan creation. The researcher's participatory process proposal, research project outline and how she would offer her work services to the participatory process development, were written into the tender. These inclusions followed on from a couple of discussions of mutual interests between the estuary manager and researcher, and a project proposal that the researcher had sent to the estuary manager prior to the tender writing. The process for the plan creation outlined in the tender (HSC 2006a) was largely based on the methodology outlined in Daniell et al. (2006) and Daniell and Ferrand (2006) that had been based on the Tsoukiàs (2007) model, and was to include a series of two to four stakeholder workshops and an external document review. During the tender process, one consultant out of the number who applied to manage the project rang the researcher before submitting his tender proposal to clarify, consult and negotiate over the number, scope and dates of the workshops to gain a preliminary agreement with the researcher on having three workshops. This consultant headed the consortium of private environmental engineers and planners that was finally selected through the public tender process to manage the project in collaboration with the estuary manager and the researcher.

During the project's initiation meeting of the estuary manager with the contracted project manager, researcher and a number of their colleagues, the first proposed adaptation to the decision-aiding methodology underlying the participatory process was voiced. The estuary manager stated his interest in basing the process on the Australian Risk Management Standard AS/NZ4360:2004 (Standards Australia 2004, 2006), something which had not been specifically outlined in the Tender. None of the project team members had previously used the Standard, and to their knowledge, it would be the first time that it had been proposed for use in such a broad scale, inter-organizational and participatory process. Following analysis of the Standard, the researcher found that it appeared compatible with the Tsoukiàs (2007) decision-aiding process model and only minor adjustments to the proposed workshop series would be needed. She was therefore willing to support the estuary manager's proposal. The project manager also gave in-principal support and the three workshops and external review activities of the project team were planned to follow the Standard's phases, as shown in Fig. 9.5.

Project meetings, telephone calls and emails were used to define the participants, methods, agendas and roles of the project team members in each of the workshops. With the researcher keeping an eye on the elements of the Tsoukiàs

(2007) model she wanted to elicit from the participants, as well as her knowledge of problem structuring methods and different types of evaluation models, she worked with the project manager (who also had a range of preferred methods from his previous experience in running workshops) and the estuary manager to design the methods.

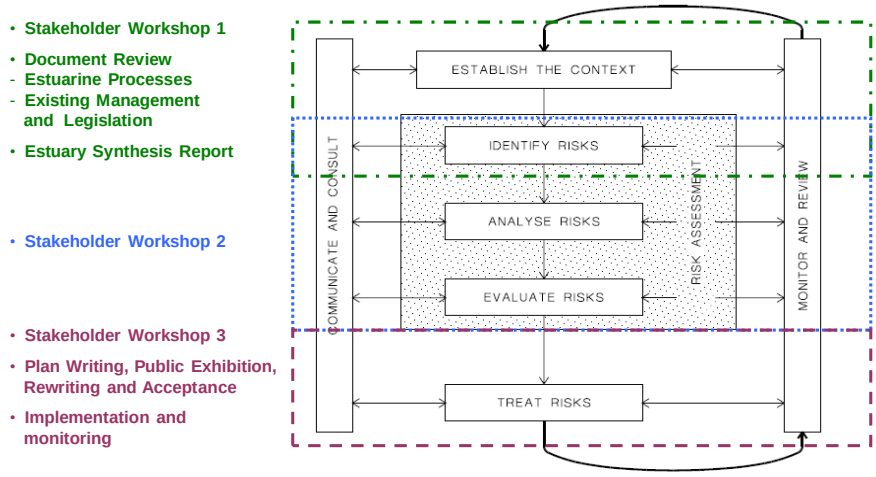

Fig. 9.5 LHEMP Participatory Risk Management Process (based on AS/NZS 4360:2004).

This collective work ranged from collaborative to heavy negotiation and compromises on some aspects of the workshop process. For example, it was originally planned to have all stakeholders participating or "implicated", according to Mazri's (2007) model, on all objects of debate in the workshops, yet prior to the second workshop heavy negotiation resulted in some of the community stakeholder members being excluded from this workshop and only given "information" on it afterwards. The researcher was mostly able to collectively design the methods used to meet her decision-aiding model needs, or successfully negotiate their use. For example, she negotiated the use of an individual card brainstorming technique for the elicitation of values, issues and goals that was then sorted in a small-group setting. Further specification of "actors" and "resources" linked to the key collectively considered values and issues (the "objects") were then elicited using pre-designed sheets with questions in these small groups. A large group discussion was then used by the project manager to create one list of the key estuarine values.

Following the first workshop, these values (relabeled as "assets" on the estuary manager's suggestion) were used by the researcher as the "points of view" (using the Tsoukiàs model terminology) to produce the "Risk Consequence Tables" to be used in the next workshop. Tables for "Likelihoods", "Risk Levels" (based on a combination of Consequences and Likelihoods (Wild River and Healy 2006)), "Knowledge Uncertainties" and "Management Effectiveness" were also produced (the "dimensions", associated "scales" and a part of the "uncertainty structure" for the evaluation model). This collection of "Risk Tables", the document review that

included 16 key risks developed in large part from the stakeholders' issues (the set of "problem statements"), and the WS1 outcomes were then distributed to stakeholders as the Synthesis Report (BMT WBM 2007), for their consideration prior to the second workshop. Due to time and competence constraints only a weighted average multi-criteria model developed in Excel was used in the second workshop with the agency and industry representatives. Results of the evaluation model calculated in real-time in front of the participants based on their risk assessments yielded that all risks were either "intolerable" or "tolerable" (and not "acceptable") meaning that they would require treatment, and hence consideration in the third workshop.

For this risk treatment workshop to define a another set of alternatives for action, the researcher was again able to negotiate the use of her preferred decision-aiding technique: her adaptation of Ackermann and Eden's (Ackermann and Eden 2001) "Oval Mapping Technique" for the development of risk treatment strategies and actions. The technique developed specifically for the LHEMP context was also used to investigate and elicit the stakeholders' views on responsibilities for actions (another set of "actors"), what indicators and data could be used for monitoring work towards risk treatment (a set of "criteria") and their priority actions and strategies (a set of "preferences"). At the end of the process, the participants' "final recommendations" were synthesized by the researcher to feed into the plan writing. The information from the strategy maps was computerized by the researcher using the Decision Explorer® software, as shown in Fig. 9.6 and exported to Excel to produce a preliminary stakeholder-based risk response (action) table.

This preliminary action table was then considered and compared to existing management plans and regional strategies by the consultants, and a final table of "risk-response" actions created. The final planned actions underwent a secondary risk assessment based on the same stakeholder value (asset) list to determine their potential efficacy for treating the estuarine risks (Coad et al. 2007, BMT WBM 2008). The draft LHEMP went on public exhibition containing 149 strategies for treating the 16 risks. Of these strategies, 32 were outlined as short-listed strategies which were suggested as having high implementation priority in terms of risk reduction potential (BMT WBM 2008). After a few minor adjustments to the plan following comments received, the final plan was accepted by the two Councils in the planning area.

During the planning process, another decision support tool was developed by the researcher just after the stakeholder-based risk response table, which could have both practical and research-oriented futures: an "actor-action-resources matrix", as shown in Fig. 9.7. The tool was designed to help analyse the distribution of actors' preferences for the strategies and actions for risk treatment created during Workshop 3, and to what extent these actors actually had authority to control these preferred actions or the resources to realise them. The eventual aim of the tool was to discover mismatches between priorities and capacities for actors to realise their preferred actions and to determine whether opportunities existed for bi-

lateral or multi-lateral negotiations to discuss how any mismatches might be overcome and resources distributed efficiently between actors to meet the most priorities possible.

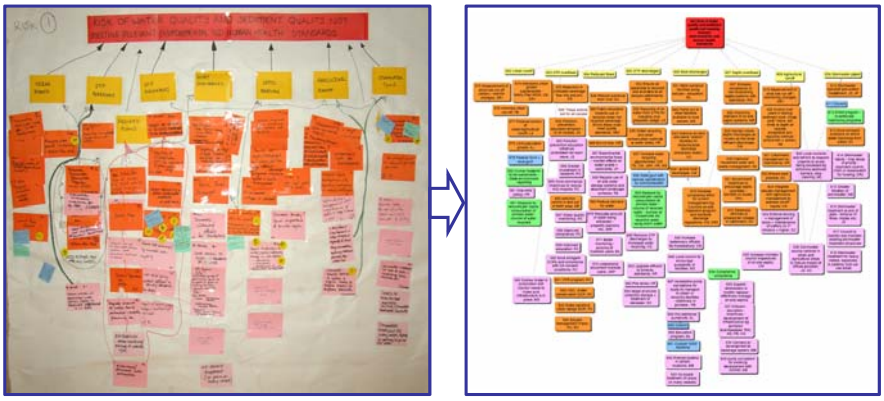

Fig. 9.6 Electronic conversion of an example paper risk treatment strategy map using Decision Explorer®.

4.2 Lessons Learnt

The LHEMP real-world decision-aiding process was a very rich learning experience. However, only a couple of lessons will be outlined here. One of the most important lessons is the need for decision-aiding analysts to be able to adapt their "ideal" theoretical methodologies to the constraints of complex and dynamic political and social arenas. Analysts therefore require not only a solid body of technical knowledge, but also social and political "nous" including strong negotiation skills and a capacity to learn and adapt quickly to changing environments if they are to use their theoretical models successfully.

Due to a range of real-world constraints and new goals and interests entering the planning process, both in its design and implementation phases, a number of methodological ideals, from the researcher's point of view, could not be met. For example, a multi-criteria analysis approach had been suggested in the initial participatory process proposal, with the idea being to construct the evaluation model based on solid decision theory (Keeney and Raiffa 1976, Roy 1985, Bouyssou et al. 2000, Bouyssou et al. 2006).

Yet a number of constraints meant that much more rudimentary forms of matrix analysis were used. These real-world constraints included: project team members' insufficient proficiency in the methods to make the underlying mathematical assumptions understandable to their colleagues and the participants; and a lack of time to gain and sort weighting or rank preferences. In the end, the risk assessment multi-criteria model used a simple weighted average approach, which as stated in Bouyssou et al. (2000) may compromise the real "meaning" of the final numbers.

However, strangely, when the researcher discussed this issue with the other project team members and process participants, it incited little to no reaction. From this case it appeared that, as long as the project team members are seen to have a legitimacy to manage the process and the underlying mathematics of models, the final results will be accepted with ambivalence, as long as obvious discrepancies between intuitive and calculated results can be logically argumented. This insight is drawn in particular from the discussion and later acceptance of the low prioritized ranking of the "water quality" risk, which was intuitively labeled as of high or medium priority by all participants (Daniell 2007b).

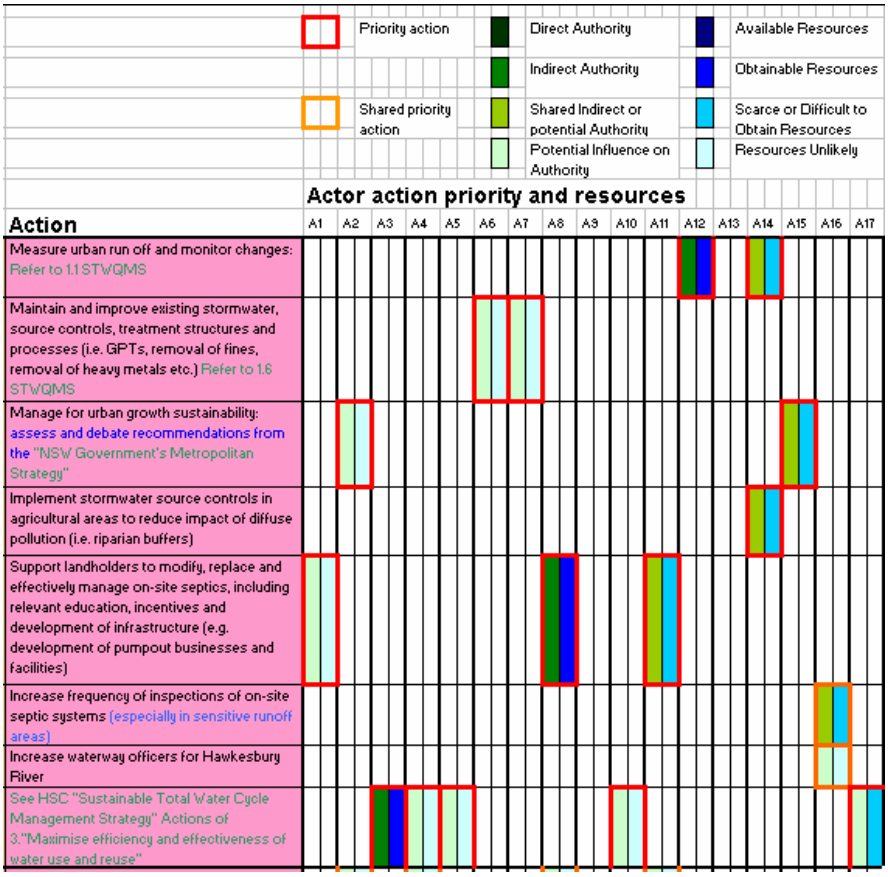

Fig. 9.6 Screenshot of the "actor-action-resources matrix tool" trialled for the LHEMP.

On the issue of analysts working as part of a complex social and political arena, there was much evidence that the project team, as well as some core process participants and associated stakeholders, all played a critical role in changing or influencing the direction of the process and the design of methods. Through this pro-

ject, personal and common objectives on the design needs changed at a number of points through the process, and divergences in the objectives and representations of the process, its interests and its possible futures under different scenarios became apparent. These divergences appeared and had to be negotiated through, despite the fact that a tender had been written and legal contract signed for the project's realization in a particular form. As in other projects, such as in engineering construction, "variations" to the contract on the decision-aiding process could be introduced at any time by any party after the signing of the contract and negotiated until a decision to alter the contract is made. The decision-aiding analysts' role in the process is therefore not fixed just from an initial agreement but must be continuously negotiated and legitimated by other project team members and participants throughout the process. Evaluation procedures for both project team members and participants, as were used throughout the LHEMP (Daniell 2007a, b, Jones et al. 2008), can help to determine and aid the building of this legitimacy and early resolution of any problems.

4.3 Insights for Theory

This real-world case of decision-aiding also provided us with valuable insights and potential deficiencies or incoherencies in the theoretical decision-aiding participatory structure model (Mazri 2007) and the process model (Tsoukiàs 2007). Analyzing *ex-post* the iterative process in our case to create and alter the participatory structure which occurred through the initiation, design and implementation phases of the participatory processes, we observed that the iteration loop ("yes/no" decision point in Fig. 9.2) in our case typically occurred after Step 4 rather than Step 3. In other words, full proposals of the participatory structure for decision-aiding were developed before reassessment by the decision-makers in the project team. This shows that the theory of the model based on constructivist principles (Mazri 2007), is not necessarily adhered to in reality. Also, due to the multiple decision-makers on the participatory structure design, each element represented in the model was subject to debate. Consensus was not always reached on definitions for each of the elements and each decision-maker often only had a partial, unnegotiated understanding of some elements, such as the resources required for each object of debate. In particular for the risk assessment process, required levels of time and competence for organizing and completing the process could have been better planned. The insights produced from the analysis of the participatory structure design undertaken in the LHEMP show how using explicitly Mazri's (2007) model during practice could promote improvements in shared understanding of the elements and the resulting participatory decision-aiding process.

Using Tsoukiàs' (2007) model in practice also led to a number of insights. These included that many of the elements outlined in the different meta-objects of the model were elicited iteratively through the decision-aiding process and not necessarily in the prescribed order. In particular, the elements of the "evaluation model" were elicited alongside the problem situation and problem formulation elements. One example is that the criteria for assessment in the risk "evaluation

model" were developed directly from participants' values elicited in the "problem situation" construction phase, as described above. Another potential issue for using the model in practice was its capacity to be translated or adapted to match topics of interest stemming from other disciplines or decision-aiding methodologies. Linked to the previous example of "values" elicited in the first workshop, it was a challenge to decide in certain cases, such as the value "good water quality", if they were "objects", "resources", "points of view" or "preference criteria". Otherwise, the researcher found the model a useful way to focus her attention on the careful design of methods to be used in the workshops. The "uncertainty structure" element was, in particular, the inspiration for creating an extra "knowledge uncertainty" and the "management effectiveness" categories used as part of the risk assessment model.

5 Discussion

Through the theoretical and practical intervention work on decision-aiding outlined in this chapter, a number of key issues to point out in this discussion have emerged. Firstly, the importance of having one or a number of decision-makers (or their close organizational representatives who can carry the decision-makers' interests) involved in co-constructing the decision-aiding artifacts from the beginning of the process should not be underestimated.

From our experiences of participating in and analyzing what took place in the LHEMP decision-aiding process, which resulted in a regionally accepted action plan, we suggest taking decision-maker inclusion even one step further; to attempt to promote decision-aiding processes that are "management-driven" rather than "research-driven". There is an important difference in both approaches, as in management-driven processes, the decision-makers have already appropriated the process as their own, meaning concrete outcomes are more likely. Of course, exactly which decision-makers are involved in the design, and how they end up biasing the participatory process towards their own interests, could have some negative impacts, including the rejection of final recommendations by other decision-makers or excluded organizations if the co-design process is not adequately managed. There are reasons why some decision-analysts prefer "research-driven" decision-aiding processes, in particular as the researcher(s) or analyst(s) typically have more control over the final decisions of what decision-aiding methodology and methods are used. Keeping this control typically allows analysts to use methods and models that may be more scientifically valid. However, whether future decision-makers will understand them and support the recommendations stemming from the models through to final decision-making is less certain if they feel little ownership over the process and have to carry on the next implementation phases without the analysts' or researchers' help. Considering the need for much real-world inter-organizational decision-aiding we therefore suggest that supporting management-driven processes are likely to achieve more positive outcomes,

even if there are some unfortunate trade-offs for the analysts between scientific validation and stakeholder legitimization of the decision-aiding process.

This means for researchers and decision-analysts that they must become much more effective negotiators in project team meetings to attempt to foster both scientifically valid method use and broad-scale stakeholder legitimization of the processes. They should play an active intervention role in the co-construction of the decision-aiding methodology and its implementation, attempting to allow decision-makers ownership over the process while contributing their specialist knowledge of decision-aiding models and problem structuring methods to the process.

Another issue of discussion is that multi-stakeholder or inter-organizational decision-aiding processes are often considered to be inefficient in terms of time and other resources for the ends that they achieve (Korfmacher 2001). However, from the LHEMP case outlined in this chapter, we would contend that *using good decision-aiding theory as a part of effective project team work efforts, can support efficient and effective inter-organizational decision-making processes*. Using the available theory, decision-aiding models and knowledge of practical advantages and disadvantages of different problem structuring methods and evaluation model types was a key in the LHEMP intervention to be able to creatively choose and collectively construct methods adapted to the process. Good theory, whether it is tacit or explicit, is invaluable for effective practice, so it makes sense to use the best available decision-aiding theory to inform real-world decision-aiding practice. This opens up a large research field on reviewing, using and creating decision-aiding theory and models appropriate to aid multi-accountable groups, as represented in Fig. 9.1. The expansion and use of the Tsoukiàs (2007) decision-aiding process model was one example in this chapter of what research in this field could constitute. Operationally testing the Mazri (2007) participatory structure design model in other intervention cases, potentially with the iteration loop after Step 4, is another immediate research need.

6 Conclusions

In this chapter we have set out to present what decision-aiding in a participatory situation in the real world, in particular for water management, may constitute. We first outlined the context that this decision-aiding must take place in – "messy" inter-organizational settings – as well as some of the available decision-aiding theories and models that could be applied. An adapted inter-organizational decision-aiding process model based on Tsoukiàs (2007) was developed and was used as the basis of the first author's research intervention in the creation of the Lower Hawkesbury Estuary Management Plan in Australia. The model significantly aided the structuring of the decision-aiding process and promoted insights on its usefulness and validity. The case also provided *ex-post* operational validation of Mazri's (2007) decision-aiding model for participatory structure design, with the exception of one feedback loop. From the case we also justified our claims that: 1) we need decision-aiding methodologies to improve inter-

organizational decision-making for water management, as well as theoretical models and problem structuring methods that can form useful parts of these methodologies; and 2) we need negotiation skills, amongst others, for putting the methodologies in place in the real world.

Acknowledgements

Thank you to all workshop participants of the LHEMP, as well as the organisers and supporters of the process including: Peter Coad, Philip Haines, Ian White, Natalie Jones, Michael Baker, Verity Rollason, Michelle Fletcher, Kristy Guise, Ross McPherson, Nils Ferrand, Stuart Burn and Pascal Perez.

References

Ackermann, F., and C. Eden. 2001. SODA and Mapping in Practice. *In* J. Rosenhead, and J. Mingers, editors. *Rational analysis for a problematic world revisited: problem structuring methods for complexity, uncertainty and conflict*. John Wiley and Sons, Chichester, UK, Pages 43-60.

Akkermans, H. 2001. Renga: a systems approach to facilitating inter-organisational network development. *System Dynamics Review* **17**:179-193

Alexander, E. R. 1993. Interorganizational Coordination: Theory and Practice. *Journal of Planning Literature* **7**:328-343

Arnstein, S. R. 1969. A ladder of citizen participation. *Journal of American Institute of Planners* **35**:216-224

Avenier, M.-J., L. Nourry, and M. Sweeney. 1999. Sciences of the Artificial and Knowledge Production: The Crucial Role of Intervention Research in Management Sciences. *Design Issues* **15**:55-70

BMT WBM. 2007. *Lower Hawkesbury Estuary Synthesis Report*. Prepared for the Hornsby Shire Council, NSW, Australia. Pages 175.

BMT WBM. 2008. *Lower Hawkesbury Draft Estuary Management Plan*. R.N1252.003.01.EMP. BMT WBM. Prepared for the Hornsby Shire Council, NSW, Australia

Bouyssou, D., T. Marchant, M. Pirlot, P. Perney, A. Tsoukiàs, and P. Vinke. 2000. *Evaluation and Decision Models: A Critical Perspective*. Kluwer Academic, Dordrecht.

Bouyssou, D., T. Marchant, M. Pirlot, A. Tsoukiàs, and P. Vinke. 2006. *Evaluation and Decision Models:stepping stones for the analyst*. Springer Verlag, Berlin, Germany

Brown, R. V. 1989. Toward a prescriptive science and technology of decision aiding. *Annals of Operations Research* **19**:467-483

Capurso, E., and A. Tsoukiàs. 2003. Decision aiding and psychotherapy. *Bulletin of the EURO Working Group on MCDA* **3**. [online] URL: http://www.inescc.pt/~ewgmcda/OpCapurso.html

Checkland, P. B. 1981. *Systems Thinking, Systems Practice*. John Wiley, Chichester, UK

Coad, P., P. Haines, K. A. Daniell, K. Guise, and V. Rollason. 2007. *Integration of Environmental Risk Assessment Within Estuary Management Planning for the Lower Hawkesbury-Nepean River, New South Wales*. 16th NSW Coastal Conference, Yamba, NSW, Australia. [online] URL: http://www.coastalconference.com/2007/papers2007/Peter%20Coad.doc

Cornwall, A. 1996. Towards participatory practice: participatory rural appraisal and the participatory process. I*n* K. de Koning, and M. Marion, editors. *Participatory Research in Health: Issues and Experiences*. Zen Books Ltd, London. Pages 94-107. [online] URL: http://www.acdi-cida.gc.ca/INET/IMAGES.NSF/vLUImages/CapacityDevelopment/$file/AndreaCornwall-E.PDF

Creighton, J. L. 2005. *The Public Participation Handbook: making better decisions through citizen involvement*. Jossey-Bass, San Francisco, CA

CSIRO. 2007. *Climate Change in the Hawkesbury Nepean Catchment*. Prepared for the NSW Government by the CSIRO, NSW, Australia

Daniell, K. A. 2007a. *Summary Report: Community Workshop 1 for the Lower Hawkesbury Estuary Management Plan*. Available as Appendix A in: BMT WBM, Lower Hawkesbury Estuary Synthesis Report, prepared for the Hornsby Shire Council, NSW, Australia. Pages 111-165.

Daniell, K. A. 2007b. *Summary Report: Stakeholder Workshops 2 & 3 for the Lower Hawkesbury Estuary Management Plan*. Report prepared for the Hornsby Shire Council and BMT WBM. Australian National University, Canberra, Australia. Pages 92.

Daniell, K. A., and N. Ferrand. 2006. *Participatory Modelling for Water Resources Management and Planning*. Pages 58. Report D3.8.2. Aquastress IP, EU FP6, Europe

Daniell, K. A., I. White, N. Ferrand, A. Tsoukiàs, S. Burn, and P. Perez. 2006. *Towards an art and science of decision aiding for water management and planning*.CD-ROM Proceedings of the 30th Hydrology & Water Resources Symposium, Launceston, Australia

Digenti, D. 1999. Collaborative Learning: A Core Capability for Organizations in the New Economy. *Reflections* **1**:45-57. [online] URL: http://mitpress.mit.edu/journals/SOLJ/Digenti.pdf

DPI. 2006. *NSW Oyster Industry Sustainable Aquaculture Strategy - Final Report*. Fisheries Division, NSW Department of Primary Industries, Australia

Eden, C. 1989. Using cognitive mapping for strategic options development and analysis. *In* J. Rosenhead, editor. *Rational analysis for a problematic world: problem structuring methods for complexity, uncertainty and conflict*. John Wiley and Sons, Chichester, UK. Pages 21-42

Eden, C., and F. Ackermann. 2001. SODA - The Principles. I*n* J. Rosenhead, and J. Mingers, editors. *Rational analysis for a problematic world revisited: problem structuring methods for complexity, uncertainty and conflict*. John Wiley and Sons, Chichester, UK. Pages 21-41,

Fischer, F. 1990. *Technocracy and the politics of expertise: critical perspectives on the managerial and policy sciences*. Sage Publications, Newbury Park, CA

Forrest., K., and A. Howard. 2004. *Central Coast: Regional Profile and Social Atlas*, NSW, Australia.[online] URL: http://www.gosford.nsw.gov.au/customer/document_gallery/social_atlas/

Friend, J. 1993. Searching for appropriate theory and practice in multi-organizational fields. *Journal of the Operational Research Society* **44**:585-598

Friend, J., and A. Hickling. 1987. *Planning under pressure: the strategic choice approach*. Pergamon Press, Oxford, UK

Gleick, P. H., H. Cooley, D. Katz, E. Lee, J. Morrison, M. Palaniappan, A. Samulon, and G. H. Wolff. 2006. *The world's water 2006-2007: the biennial report on freshwater resources*. Island Press, Washington DC

Habermas, J. 1984. *The Theory of Communicative Action,*. Polity Press, Oxford, UK

Habermas, J. 1996. *Between facts and norms*. Polity Press, Cambridge, UK

HNCMA. 2005. *Hawkesbury-Nepean Draft Catchment Action Plan 2006-2015*. Hawkesbury Nepean Catchment Management Authority, NSW, Australia

HSC. 2006a. *Q26/2006 Lower Hawkesbury Estuary Management Plan - Tender Document*. Water Catchments Team, Hornsby Shire Council, NSW, Australia

HSC. 2006b. *Summary of the 2006 State of the Environment Report*. Environmental Health and Protection Team, Hornsby Shire Council, Hornsby, NSW, Australia. Pages 23.

Hutton, D., and L. Connors. 1999. *A history of the Australian environmental movement*. Cambridge University Press, Cambridge, UK

Jones, N. A., P. Perez, T. G. Measham, G. J. Kelly, P. D'Aquino, K. A. Daniell, A. Dray, and N. Ferrand. 2008. *Evaluating participatory modeling: Developing a framework for cross-case analysis*. Pages 44. Socio-Economics and the Environment in Discussion (SEED). CSIRO Working Paper Series, 2008-11. July 2008. [online] URL: http://www.csiro.au/files/files/plqu.pdf

Keeney, R., and H. Raiffa. 1976. *Decision with Multiple Objectives: Preferences and Value Trade-offs*. John Wiley and Sons, New York

Kimmerikong. 2005. *Hawkesbury-Nepean River Estuary Management - Scoping Study - Final Report*. Kimmerikong Pty Ltd Natural Resource Management, NSW, Australia

Korfmacher, K. S. 2001. The Politics of Participation in Watershed Modeling. *Environmental Management* **27**:161-176

Landry, M., C. Banville, and M. Oral. 1996. Model legitimisation in operational research. *European Journal of Operational Research* **92**:443-453
Landry, M., J. L. Malouin, and M. Oral. 1983. Model validation in Operations Research. *European Journal of Operational Research* **14**:207-220
MacKenzie, K. D. 1986. Virtual Positions and Power. *Management Science* **32**:622-642
Mazri, C. 2007. *Apport méthodologique pour la structuration de processus de décision publique en contexte participatif. Le cas des risques industriels majeurs en France.* LAMSADE, Université Paris Dauphine, Paris. Pages 393.
Miller, B. M., and D. C. van Senden. editors. 2003. *Brooklyn Estuary Processes Study*. Water Research Laboratory, The University of New South Wales, Manly Vale, NSW, Australia
Mingers, J., and J. Rosenhead. 2004. Problem structuring methods in action. *European Journal of Operational Research* **152**:530-554
Mostert, E. 2003a. The European Water Framework Directive and water management research. *Physics and Chemistry of the Earth* **28**:523-527
Mostert, E. 2003b. *Public participation and the European Water Framework Directive. A framework for analysis*. Inception report of the HarmoniCOP project, EC contract N° EVK1-CT-2002-00120. [online] URL: http://www.harmonicop.info/_files/_down/HarmoniCOPinception.pdf
Ostanello, A., and A. Tsoukiàs. 1993. An explicative model of 'public' interorganizational interactions. *European Journal of Operational Research* **70**:67-82
Palmer, R. N., A. M. Keyes, and S. Fisher. 1993. *Empowering stakeholders through simulation in water resources planning*. I*n* K. Hon, editor. Water management in the '90s: a time for innovation, ASCE Annual Conference, 1-5 May 1993, Seattle, WA. Pages 451-454.
Rocha, E. M. 1997. A Ladder of Empowerment. *Journal of Planning Education and Research* **17**:31-44
Rosenhead, J., and J. Mingers. editors. 2001. *Rational analysis for a problematic world revisited: problem structuring methods for complexity, uncertainty and conflict - Second Edition*. John Wiley and Sons Ltd, Chichester, UK
Roy, B. 1985. *Méthodologie multicritere d'aide à la decision*. Economica, Paris, France. Translated into English by Mark R. McCord in 1996 as "Multicriteria Methodology for Decision Aiding", Kluwer Academic Publishing, Dordrecht, The Netherlands.
Standards Australia. 2004. *AS/NZS 4360:2004, Risk Management; and Companion Handbook HB 436:2004*. Standards Australia, Sydney, Australia
Standards Australia. 2006. *HB 203:2006, Environmental risk management-Principles and processes*. Standards Australia, Sydney, Australia
Thomas, R. L. 2004. Management of freshwater systems: The interactive roles of science, politics and management, and the public. *Lakes and Reservoirs: Research and Management* **9**:65-73
Tsoukiàs, A. 2007. On the concept of decision aiding process: an operational perspective. *Annals of Operations Research* **154**:3-27
Tsoukiàs, A. 2008. From Decision Theory to Decision Aiding Methodology. *European Journal of Operational Research* **187**:138-161
van den Belt, M. editor. 2004. *Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building*. Island Press, Washington, DC
Vennix, J. A. M. 1996. *Group model building: facilitating team learning using system dynamics*. John Wiley, Chichester, UK
Vinck, D., and A. Jeantet. 1995. Mediating and commissioning objects in the sociotechnical process of product design: a conceptual approach *in* D. Maclean, P. Saviotti, and D. Vinck, editors. *Designs, Networks and Strategies, Vol. 2*. EC Directorate General Science R&D, Brussels
Webler, T. 1995. "Right" discourse in citizen participation: an evaluative yardstick. I*n* O. Renn, T. Webler, and P. Wiedemann, editors. *Fairness and competence in citizen participation: evaluating models for environmental discourse*. Kluwer Academic, Dordrecht. Pages 35-86.
Wild River, S., and S. Healy. 2006. *Guide to Environmental Risk Management*. CHH Aust. Ltd, Sydney, Australia