

Interactive problem structuring with ICZM stakeholders

FRANK VAN KOUWEN
CAREL DIEPERINK
PAUL P. SCHOT
MARTIN J. WASSEN
Copernicus Institute, Utrecht University
Utrecht, The Netherlands

Integrated Coastal Zone Management (ICZM) is struggling with a lack of science-management integration. Many computer systems, usually known as “decision support systems”, have been developed with the intention to make scientific knowledge about complex systems more accessible for coastal managers. These tools, allowing a multi-disciplinary approach with multi-criteria analyses, are designed for well-defined, structured problems. However, in practice stakeholder consensus on the problem structure is usually lacking.

Aim of this paper is to explore the practical opportunities for the new so-called Quasta approach to structure complex problems in a group setting. This approach is based on a combination of Cognitive Mapping and Qualitative Probabilistic Networks. It comprehends a new type of computer system which is quite simple and flexible as well. The tool is tested in two workshops in which various coastal management issues were discussed.

Evaluations of these workshops show that (1) this system helps stakeholders to make them aware of causal relationships, (2) it is useful for a qualitative exploration of scenarios, (3) it identifies the quantitative knowledge gaps of the problem being discussed and (4) the threshold for non-technicians to use this tool is quite low.

Keywords integrated coastal zone management, problem structuring, stakeholder participation, cognitive mapping, interactive policy making

The need for simple and flexible tools

The concept of Integrated Coastal Zone Management (ICZM) endorses a wide range of management issues and involves complicated problems (Cicin-Sain and Knecht, 1998; WorldBank, 1996). Firstly, coastal managers will need to deal with knowledge from various research disciplines, including social, economic and ecological disciplines. In practice, there is often a weak link between policy-related research and the policy-making itself (Boogerd, 2005; Deelstra et al., 2003; in 't Veld, 2000). The weakness of this link in ICZM is described by Cicin-sain and Knecht (1998) as a lack of science-management integration. Secondly, ICZM decision-making is complicated because the decisions to be made usually affect many stakeholders. These stakeholders may have interests from economic, social and ecological perspectives and will have different perceptions of the problems. How to deal with these diverging parties and how to involve them in the decision-making process?

Using Hisschemöller's typology (Hisschemöller, 1993), many problems faced in ICZM can be classified as *unstructured* problems, in the sense that they are characterised by both lack of certainty regarding relevant knowledge and lack of consensus on relevant norms and values. Therefore, to deal with many environmental issues, problem structuring will be necessary as a start (Boogerd, 2005; Hisschemöller and Hoppe, 2001). For this purpose, more open and participatory policy processes can be helpful (see for example Geurts and Joldersma (2001), Hisschemöller et al. (2001), Hjørtsø (2004), Korfmacher (2001), Mendoza and Prabhu (2005), Ravetz (1999) or Van Asselt and Rijkens-Klomp (2002)). These studies emphasise that environmental policy-making should start with discussion sessions in which policy-makers,

Address correspondence to Frank van Kouwen, Copernicus Institute, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands. E-mail: F.vanKouwen@geo.uu.nl

stakeholders and researchers should participate. In coastal management, policy processes should be more open and flexible, including active involvement of stakeholders (Treby and Clark, 2004). This is especially important in an early stage of the decision-making process (UNEP, 1999; WorldBank, 1996).

To structure participatory sessions, appropriate methodologies will be required. Many computer systems, usually called “Decision Support Systems” or “Planning Support Systems”, have been developed with the intention to make knowledge about complex systems better accessible for policy-makers. However, the use of these systems in practice is limited (Uran, 2002; Vonk, 2006). One of the main reasons is that these systems are designed for complex tasks, whereas the users prefer simple tools performing simple tasks (Vonk et al., 2006). Furthermore, the systems lack user friendliness, transparency and versatility (Vonk et al., 2005). Only few tools are designed for problem structuring with stakeholders (van Kouwen et al., 2007a). There exist a number of tools that allow for a multi-disciplinary approach, using multi-criteria analyses (MCA, see Bell et al., 2003; Bower and Turner, 1998; Brouwer, 2000; Dragan et al., 2003; Gregory and Wellman, 2001; Hämäläinen et al., 2001; Turner, 2000). However, MCA is not effective if the set of variables does not match the aspects that stakeholders consider to be relevant. Prior to using these types of advanced computer systems, there is need for simple and exploratory tools to structure complex problems in participatory settings.

Cognitive Mapping as a computer tool: the *Quasta* approach

A technique called Cognitive Mapping (CM, also called mental model mapping, cause mapping or concept mapping) can be helpful to identify and structure problems as seen from the perspectives of certain groups or individuals (Axelrod, 1976; Kolkman et al., 2005; Soini, 2001). This approach results in graphical networks consisting of nodes representing concepts, and arrows representing causal relationships among these concepts. A useful step forward is to use the computer for reasoning and calculation of these schemes and networks. For this purpose, the formalism of Fuzzy Cognitive Maps (FCMs) can be used (Khan and Quaddus, 2004; Özesmi and Özesmi, 2004). However, FCMs assume linear, quantified relationships. For unstructured environmental problems, this is mostly not the case. This is problematic since even a single non-linear relationship in a system may cause a completely unrealistic dynamic behaviour of a FCM model representing that system. Wellman (1990) found another way of computer reasoning with cognitive maps; he adopted the concept of Qualitative Probabilistic Networks (QPNs) and proposed to use these for inference in cognitive maps (Wellman, 1994). Van Kouwen et al. (2007c) showed that the concept of QPNs can be used to link CM and formal modelling. The QPN formalism is useful for inference in cognitive maps, because:

1. The graphical part of a QPN is a directed graph. As a cognitive map is basically a directed graph too, the formalism can be used as an analytical extension of cognitive maps (Wellman, 1994).
2. Algorithms exist (Druzzdel and Henrion, 1993; van Kouwen et al., 2007b), which allow observations to be entered into a QPN and that calculate the qualitative effects rapidly. This creates the opportunity to use a QPN interactively in a discussion group setting.
3. The formalism of QPNs is based on Bayesian Belief Networks (Wellman, 1990), which are developed for reasoning under uncertainty (Pearl, 1988). In many environmental problems it is necessary to deal with uncertainty (van Asselt, 2000).
4. Policy-making has a need for both forecasting (scenario-analysis) and backcasting (optimisation) (Holmberg, 1998; Robinson, 2003). Computer tools are needed to provide both capabilities (van Kouwen et al., 2007a). This can be addressed with QPNs as these allow reasoning in the direction of arrows, as well as reasoning in the opposite direction.

A general disadvantage of QPNs is that these do not allow feedback loops. However, this problem has been addressed by Van Kouwen et al. (2007c) by using an heuristic approach that allows inference in cognitive maps with feedbacks. Aim of this paper is to explore the practical opportunities of this QPN-based technique for computer-supported interactive policy-making. This paper presents the results concerning a number of hypotheses which were empirically tested in discussion groups. These hypotheses are:

1. this system helps stakeholders to make them aware of causal relationships;
2. it helps in exploring possible scenario's;
3. it identifies what further (quantitative) knowledge is needed.
4. the threshold for non-technicians to use this tool is not an obstacle;

To test these hypotheses, an interactive cognitive mapping computer tool has been implemented, which is called *Quasta*. The *Quasta* tool has been used in problem-structuring workshops in which stakeholders, policy makers and researchers participated. The added value of the approach has been determined by means of questionnaires and additional interviews.

Definitions

Cognitive Mapping

To identify the problems as seen from the perspectives of certain groups or individuals, the CM technique, also known as mental model mapping, cause mapping or concept mapping, can be helpful (Kolkman et al., 2005; Soini, 2001). Basically, a cognitive map is the representation of thinking about a problem. This representation is by means of maps, which consist of a network of nodes representing concepts and arrows representing relationships. In this particular type of digraph the direction of the arrow implies believed causality (Eden, 2004). Up to this point there is agreement about the definition of a cognitive map in scientific literature. However, when it comes to further elaboration of the semantics and the analyses of these maps, there exist crucial differences between the various authors (Marchant, 1999). For this study, we use the cognitive maps as defined and described by Axelrod (1976). In this definition the nodes represent variables taking their values in ordered sets and the arrows represent causal assertions; the arrows can be positive or negative. A positive arrow from *A* to *B* means that an increase of *A* is believed to cause an increase of *B*. A negative arrow from *A* to *B* means that an increase of *A* will cause a decrease of *B*.

In properly constructed cognitive maps, the heads of the map (i.e. the end nodes that do not link to other nodes), will depict *goals* and the tails (i.e. the nodes that is not linked to) will depict potential action points or options (Eden, 2004). In cognitive maps in this paper, a positive relationship is depicted with a regular arrow, a negative one with an arrow having a circle on its tip. Figure 1 shows an example of such a cognitive map.

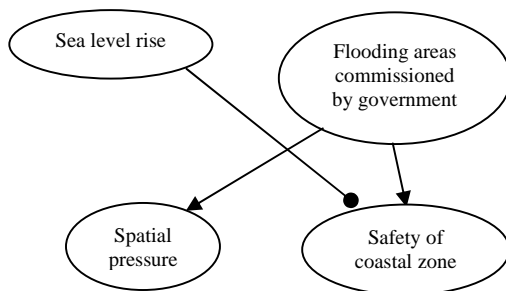


Figure 1: An example cognitive map

The cognitive map in Figure 1 captures some of the issues which are typical for the densely populated coastal zone in the Netherlands. A sea level rise negatively influences the safety of the coastal zone. To prevent this, the government may propose some commissioned areas which, in case of high (sea) water levels, are designated to flood. However, this measure would imply that inhabitants of these areas should move out; the spatial pressure, which is already very high in the Netherlands, would increase. An effect over a one-way trail of causal links, like the sea level rise reducing the safety, is called a *direct effect*. This does not mean that there can't be a 'chain' of effects; for example, more of *A* causes more of *B* and more of *B* causes more of *C*. In this situation, an increase of *A* is said to give a direct effect onto *C*. It is called a direct effect as long as the trail follows the direction of the arrows. A certain measure may cause multiple effects. If a measure is aimed to meet a certain goal, but it gives also (undesired) effects on other goals, this

is called a *side-effect*. The flooding areas of Figure 1 bring side-effects with them; it will result in (even more) spatial pressure. Side-effects may result in *dilemmas*: if you choose to take measures for one goal, you will automatically work against another goal.

Qualitative Probabilistic Networks

Qualitative Probabilistic Networks (QPNs) are a qualitative abstraction of Bayesian Belief Networks (BBNs). The latter networks are developed to deal with uncertainty, and can be applied to cases in which there is uncertain, incomplete or even contradictory knowledge (Pearl, 1988). The QPNs have been developed by Wellman (1990). A QPN is similar to a BBN in the sense that they both contain a graphical part that represents the independencies between variables: an a-cyclic directed graph (digraph). The difference is that a BBN has a quantitative part containing the exact joint probability distributions among variables, whereas a QPN only contains restrictions on these joint probability distributions (Renooij, 2001). These restrictions are defined in terms of qualitative probabilistic relationships. The relationships can be one of four qualitative influences: positive, negative, zero or ambiguous. These influences are represented by the following signs: '+', '-', '0' and '?' respectively. The same signs are used for representing the observed or calculated effect on a variable.

Formally, a QPN is a pair (G, Q) , in which $G = (V(G), A(G))$ is an a-cyclic digraph G consisting of a set of vertices V and a set of arcs A . In the definition Q is a set of qualitative probabilistic relationships. There exist two types of qualitative probabilistic relationships: qualitative influences and qualitative synergies. Qualitative influences consist of influences from one variable onto another; qualitative synergies describe the interactions among multiple variables. The set of qualitative probabilistic relationships Q can contain both of these relationships. However, synergies only make a difference when we want to analyse the effect of an observation, given another earlier observation. For our purpose it is sufficient to have only single observations, or multiple simultaneous observations. By definition, synergies do not apply in case of a single observation. In case of multiple simultaneous observations, the synergies will be overruled by the qualitative influences (Renooij, 2001).

For a more detailed definition of QPNs, we refer to the PhD thesis of Renooij (2001) or the paper of Van Kouwen et al. (2007b) about a revised algorithm for QPNs. Important in our research is that observations on variables can be entered into a QPN, and that there exist several inference algorithms which can calculate the effect of an observation on the other variables in the network. We are using an adapted version of the *sign-propagation* algorithm. This algorithm was originally developed by Druzdel and Henrion (1993), but has been revised by Van Kouwen et al. (2007b). In a QPN, the qualitative influences are only defined for each of the vertices in the digraph. This algorithm uses the fact that the set of all qualitative influences can be derived with the following rules:

Symmetry. This means that if A has a positive influence on B , then B will have a positive influence on A . This applies to each of the four signs, and applies also to indirect influences (see the next rule of transitivity)

Transitivity. This means that if A influences B , and B influences C , then A will influence C . The resulting influence will be equal to the sign-product (defined with the operator \otimes from figure 1) from the signs of the first and second influence. An influence from A to C through B is called an indirect influence (B can be either a single vertex or a chain of vertices).

Composition. This means that the effect of multiple influences (either direct or indirect) is equal to the sum of these influences, which is defined with the \oplus operator, see figure 1.

For a proof of these rules, we refer to Wellman (1990) and Renooij (2001).

\otimes	+	0	-	?
+	+	0	-	?
0	0	0	0	0
-	-	0	+	?
?	?	0	?	?

\oplus	+	0	-	?
+	+	+	?	?
0	+	0	-	?
-	?	-	-	?
?	?	?	?	?

Figure 1. The \otimes and \oplus operator

We use the adapted version of the sign-propagation algorithm as described by Van Kouwen et al. (2007b), since it is proven that this version gives no unnecessary ambiguity and no incorrect zero influences.

Problem-structuring workshops

To test the use of the new approach in practice, an implementation of the computertool was required. We implemented the QPN algorithms in Java™, and named the application *Quasta*. More technical information can be found in the papers of Van Kouwen et al. (2007b; 2007c). We also used the public domain software GeNIe developed by the Decision Systems Laboratory (DSL, 2006). The qualitative tool (QGeNIe) of this package, was used as a graphical user interface. The Quasta tool reads a QGeNIe file, extracts instructions from annotations, calculates the effects and writes the results back into the file.

The Quasta tool has been evaluated in two interactive workshops. In these workshops, sustainability issues with respect to coastal management were discussed. The cases can be considered as representative for complex, unstructured problems. A brief description of both of these workshops can be found in Box 1.

The first workshop took place in September 2006 in Concepción, Chile. The symposium was organised by the CENSOR INCO-project ('Climate variability and El Niño Southern Oscillation: Implications for Natural Coastal Resources and Management') in combination with the Pasarelas project, which is about 'Interface Tools for Multi-stakeholder Knowledge Partnerships for the Sustainable Management of Marine Resources and Coastal Zones' (CENSOR, 2007). In the workshop 11 persons participated, from various backgrounds (scientists, executives from governmental departments in Peru and Chile, people from local fishing communities, etc.). The language was Spanish and the topic of discussion was *restricted management areas for fisheries*.

The second workshop was part of the project 'Sustainable living in the Dutch coastal zone', which was an exploratory project about the Dutch coastal zone in 2080. Eight persons participated in this workshop, which was held in October 2006, in Delft, The Netherlands. The group of participants included researchers, consultants and policymakers. The language was Dutch and the topic of discussion was *living in the Dutch coastal zone in 2080*. More specifically, a scenario was discussed in which the Dutch people have a flexible, sea-friendly attitude and economic values are scattered throughout the country. This scenario was discussed with respect to the themes 'land use', 'economy', 'safety', 'energy', 'technology & innovation' and 'institutional aspects'.

Box 1: Brief description of the two workshops

Both discussion sessions were supervised by an independent chairman. Discussions started with abstract, vague concepts like "sustainable safety in the coastal zone" that were elaborated during the sessions. This means that the participants was asked to make these concepts as explicit as possible. This would result in a set of more definite, measurable concepts (e.g. "risk of flooding"). Once there was a -more or less- complete set of indicators for the initial concept, the chairman started to ask for possible causes of these indicators. Also, for each concept was determined what possible (other) effects these may give. By doing this step by step, relevant concepts were revealed. Gradually, the discussion changed from discussing relevant concepts to discussing the relationships among them. Relationships could be either positive, negative or unknown. If individuals disagreed about certain relationships, these were further elaborated. For instance, in some cases it was necessary to refine a concept or a relationship. This can be done by introducing new concepts.

During the sessions, an independent facilitator entered all of the mentioned concepts and relationships graphically into the computer using the QGeNIe tool. Using a high-resolution beamer, the constructed network was visible for each of the participants.

Building up the network was an iterative process of adding concepts and relationships and making them more explicit. The phase of only constructing the network is finished once:

1. Every participant agrees that the most important issues are included
2. There is (majority) agreement about the (in)dependencies

From this point, the Quasta was used for calculating qualitative effects. Usually, this started with entering desired changes (goals). For instance, the group wants the risk of flooding to be reduced. Then, running the Quasta tool would indicate what (qualitative) changes can help in achieving this, and also what side-effects these would give. Some of these changes could be impossible, or unacceptable for some participants. For these concepts, the desired or only possible directions can be entered. This is the start of an iterative process of:

- Entering (desired) changes into the network
- Seeing the (side-) effects of these changes
- Adapting the network because of new insights

The latter step is possible, since the network can be changed any time (even if some changes are fixed). This iterative process is a way of (qualitatively) exploring policy options and scenario's.

Some diagrams of the workshops

Figure 2 shows the diagram that has been constructed in the first workshop. We use the following graphical layout for the results after qualitative reasoning with the Quasta computer tool: a dark grey box with white letters represents a positively influenced variable. A light grey one with black letters indicates a negatively influenced variable. White boxes with italic grey letters represent *ambiguously* influenced variables. Finally, regular white boxes with non-italic, black letters represent variables that have not been influenced. The boxes of variables for which a direction is given ('Resources'), have a thicker edge.

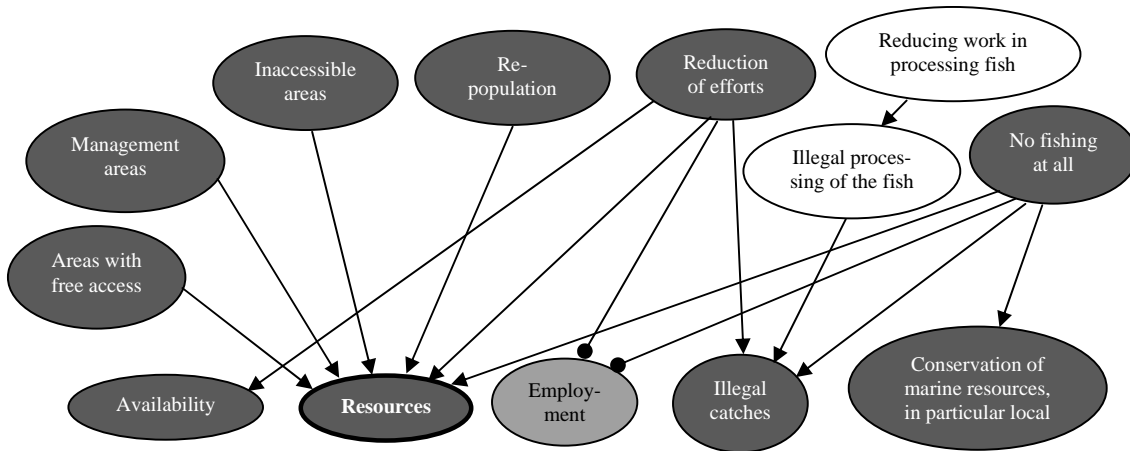


Figure 2: the diagram as constructed in workshop 1 (translated to English): more resources

The Quasta tool shows that, based on the participants' arguments, measures aimed at keeping resources will stimulate illegal catches. Figure 3 illustrates how Quasta can help in exploring the possibilities for a scenario in which resources are maintained, but illegal catches are prevented as well. It shows that, based on the participants' arguments, there should *not* be a reduction of the work in processing fish (in other words, it should increase). This would prevent the illegal processing, and therefore work against the illegal catches.

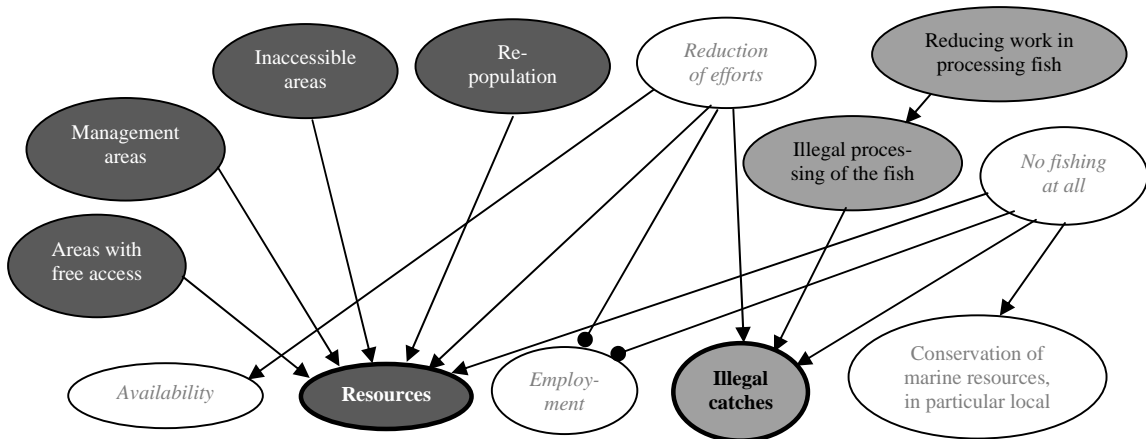


Figure 3: the diagram of workshop 1: more resources combined with battling illegal catches

The topic of discussion in workshop 2 was a lot more complex; it was an exploratory project about the Dutch coastal zone in 2080 and many thematic issues have been discussed. Some parts of the diagrams as constructed in workshop 2 are shown in Figure 4.

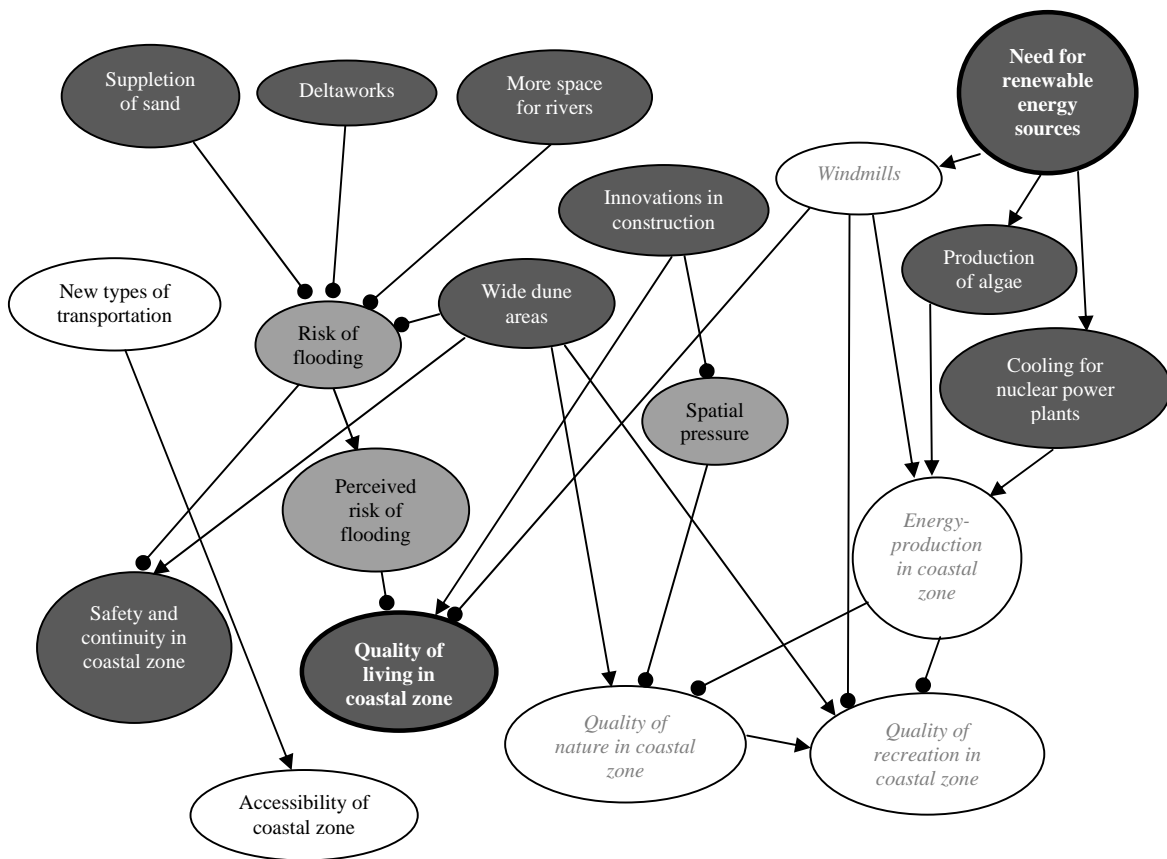


Figure 4: parts of the diagrams as constructed in workshop 2

In workshop 2, the six themes ('Land use', 'Economy', 'Safety', 'Energy', 'Technology & Innovation' and 'Institutional aspects') were discussed subsequently. In the last part of the workshop, the six resulting

diagrams were integrated by asking for inter-thematic causal relationships. Figure 4 shows some interesting parts of the integrated diagram, and explores a scenario with a high quality of living in the coastal zone, combined with an increased need for renewable energy sources. The Quasta tool shows several changes which, based on the participants' arguments, fit unambiguously into such a scenario. For instance, having wide dune areas, innovations in construction and several measures to reduce the risk of flooding.

Questionnaires and interviews

The set of hypotheses were empirically verified by means of questionnaires and additional interviews.

First of all, we asked some questions to know more about the background of the participant . Does the participant have a technical background? And has the participant ever experienced the use of techniques like CM before? Next, the participants was asked what they think about CM in general. Do causal diagrams help in visualising problems in a comprehensible manner or not? Do they help in structuring discussion sessions or not? And do these diagrams contribute to a common view of the problem or not? We then asked the participants whether they found the session useful or not. The information gathered so far gives, apart from relevant background information, an indication for the fourth hypothesis.

Our next step was aimed to find out if the participants had learned something new (hypothesis 2), and if so, how. Therefore we asked them if the session showed some relevant factors that were new to them; aspects that they weren't aware of prior to the session. If they confirmed this, we asked them if this was because others mentioned it, or because the relationships were shown by the diagram, or was it the computer-supported reasoning which showed them the dependencies? The participants were free to give multiple answers.

We then subsequently asked them to what extent they think that the methodology helps in revealing direct effects, side-effects and dilemmas. To address the second hypothesis, We asked them if they think that the tool helps in exploring scenarios, and why (not). Analogously, we addressed hypothesis 3 by asking them if the tool helps to find knowledge gaps, and why (not).

In the end, the participants were asked if they see opportunities to use this type of tool in their own working environment. If they do, they were asked what type of applications they see. If they don't, they were asked why this is (is it the tool or is it the type of environment they work in). This information is helpful for addressing the fourth hypothesis. Finally, there was some room for additional remarks.

Assessment of the usefulness of the tool

For both workshops, the results of the questionnaires and additional interviews will be presented.

Workshop 1: restricted management areas for fisheries

The most important answers (but excluding the respondents' argumentation) are shown in table one.

We will now discuss the results from the questionnaires and additional interviews.

Participants' background

The group of 11 participants was quite mixed and included scientists, executives from governmental departments in Peru and Chile, people from local fishing communities, etc. Most of them (seven) have a technical background.

Experience with and opinion about CM

Only two of the participants had experienced the use of CM before. Except for three of them, all participants considered CM as a helpful technique to visualise complex problems. Half of the group considered CM as a useful approach to structure discussions and the majority shared the opinion that CM is a means to construct a common perspective of the problem(s) at stake.

Participant has technical background?	How useful was the session?	Awareness of some new aspects?	If yes, because of the use of the computer?	Helps to identify dilemmas?	Useful for exploring scenarios?	Reveals knowledge gaps?	Applications in own working environment?
No	Useful	Yes	Yes	Neutral	Yes	Yes	Yes
No	Useful	Yes	No	Agree	No answer	No answer	Yes
No	Useful	Yes	No	Neutral	Yes	Yes	Yes
No	Useful	Yes	No	Neutral	No answer	No answer	No
Yes	Useful	Yes	Yes	Agree	Yes	Yes	Yes
Yes	Very useful	Yes	Yes	Agree	Yes	Yes	Yes
Yes	Useful	Yes	Yes	Agree	Yes	Yes	Yes
Yes	Useful	Yes	No	Agree	Yes	Yes	No
Yes	Useful	No	n.a.	Agree	Yes	Yes	Yes
Yes	Useful	No	n.a.	Neutral	Yes	Yes	Yes
Yes	Neutral	No	n.a.	Neutral	No	No	No

Table 1: Answers from participants in workshop 1.

Usefulness of the workshop

One participant thought the workshop to be 'very useful', the opinion of one person was neutral and all others classified it as 'useful'.

Consciousness of causal links

During the workshop, three out of eight participants did not see any aspects and causal links that were new to them. Most of the others saw some new causal links because others mentioned it. Three persons became aware of these links because of the graphical diagram. For four persons, the interactive use of the computer helped them to see some new relationships.

Effects and dilemmas

Except for one persons with a neutral opinion, all of the participants agreed the view that the computer tool was helpful to identify direct effects. Six of them consider the tool as being useful for identification of side-effects; one of them disagrees about this and the others' opinion is neutral. The majority of the participants agreed that the tool is useful to identify dilemmas.

Exploring scenarios

Almost all of the participants shared the opinion that the method is useful to explore scenarios qualitatively. One person disagreed about this, and suggested that the subject of the discussion is too complex for non-professionals and non-technicians. The other participants (except for two who didn't answer this question) agreed that the method is useful for qualitative exploration of scenarios. Arguments of them include that it helps to make abstract opinions more concrete, that it allows to add climatological or political scenarios, and that it clarifies the problems.

Identification of knowledge gaps

Almost all of the participants shared the opinion that the method is useful to reveal knowledge gaps. One person disagreed about this, and claimed that the relationships were already clear for him or her. The other participants (except for two who didn't answer this question) agreed that the method specifies the need for further knowledge. Arguments include that it shows what aspects you need to know more about to solve the problem, and that it helps to show effects that you wouldn't expect in the first place.

Use of the tool in own working environment

Eight out of the 11 participants suggested that they can imagine application of the tool in their own working environment. Mentioned applications include group decision-making in general, the management of natural resources and the introduction of new measures. One of the three persons who didn't see applications, suggested that the positive-negative reasoning can be confusing.

Workshop 2: living in the Dutch coastal zone in 2080

The most important results (but excluding the argumentation) are summarised in table two.

Participant has technical background?	How useful was the session?	Awareness of some new aspects?	If yes, because of the use of the computer?	Helps to identify dilemmas?	Useful for exploring scenarios?	Reveals knowledge gaps?	Applications in own working environment?
No	Useful	Yes	No	Agree	Yes	Yes	No
No	Neutral	Yes	No	Compl. disagree	No	No	No
No	Useful	No	n.a.	Compl. agree	Yes	Yes	Yes
No	Useful	No	n.a.	Compl. agree	Yes	Yes	No
No	Useful	No	n.a.	Neutral	Yes	Yes	Yes
Yes	Useful	No	n.a.	Neutral	Yes	Yes	Yes

Table 2: Answers from participants in workshop 2.

We will now discuss the results from the questionnaires and additional interviews.

Participants' background

The group of eight participants included researchers, consultants and policymakers. Only one of the six responding participants had a technical background.

Experience with and opinion about CM

Half of the group had experienced the use of CM before. Two of the six responding participants considered CM as a helpful technique to visualise complex problems. Everyone agreed that CM is a useful approach to structure discussions. Two of them thought CM to be a means to construct a common perspective of the problem(s) at stake.

Usefulness of the workshop

Except for one participant with a neutral opinion, all participants predicted the session as 'useful'.

Consciousness of causal links

Two participants acknowledged that the workshop made them aware of aspects and causal links that were new to them. This was only because others mentioned it, not because of the diagram nor the use of the computer.

Effects and dilemmas

All of the participants shared the view that the computer tool was helpful to identify direct effects. Half of the group considers the tool as being useful for identification of side-effects. One person disagrees about this and the opinion of the others is neutral. Half of the group thought the tool to be (very) useful for identification of dilemmas. Again, another person disagrees about this and the opinion of the others is neutral.

Exploring scenarios

Almost all of the participants shared the opinion that the method is useful to explore scenarios qualitatively. One person disagreed about this, and states that the system won't come up with anything new because 'you get what you give'. The other participants argued that the method gives an indication of what such a scenario looks like, it helps to clarify relationship and it reveals inconsistencies.

Identification of knowledge gaps

Almost all of the participants shared the opinion that the method is useful to reveal knowledge gaps. One person disagreed about this, but did not give any arguments for this. The other participants argued that the ambiguities and dilemmas give an indication for the required knowledge.

Use of the tool in own working environment

Half of the group suggested that they might see applications for the tool in their own working environment. Mentioned applications include long-term future planning projects.

Discussion

Each of the four hypotheses has been confirmed to a certain extent. We will discuss them subsequently.

Hypothesis 1: the system helps stakeholders to make them aware of causal relationships

Especially in the first workshop, many participants did become aware of some relationships and aspects that they didn't see before. For four participants in this workshop, the awareness was (also) because of the use of the interactive computer tool. Moreover, in both workshops most people agree that the tool helps to identify dilemmas. Therefore, it can be concluded that the tool contributes to awareness of these dilemmas and as such it stimulates social learning.

Hypothesis 2: it helps in exploring possible scenario's

In both workshops, almost all of the participants confirmed that the methodology helps in exploring scenarios. As such, we may conclude that the tool has given a useful contribution to the discussion. Repeatedly, it is argued that the tool helps in this respect because it clarifies relationships and shows inconsistencies.

Hypothesis 3: it identifies what further (quantitative) knowledge is needed

As for the second hypothesis, almost all of the participants confirmed that the methodology helps in revealing knowledge gaps. Participants have argued that the ambiguities and dilemmas show what further (quantitative) knowledge is necessary to tackle the problem(s).

Hypothesis 4: the threshold for non-technicians to use this tool is not an obstacle

The results as shown in the tables 1 and 2 show do not indicate that participants with a technical background are more positive than non-technicians or vice versa. Many of the non-technicians were quite positive about the methodology and 5 out of the 9 non-technicians see practical applications of the tool in their own workhood.

In comparison to the second workshop (WS2), the participants of the first workshop (WS1) are in general more positive about the tool and its added value. We will discuss some differences between the two workshops, which may give some explanation for this. The session of WS1 took only 75 minutes, whereas the duration of WS2 was more like 2½ hours. The topic of discussion in WS1 was quite focused on a specific subject, whereas the subject in WS2 was (too) broad. Another difference was that many of the participants in WS1 are really involved in fisheries and decisions to be made might actually affect them. The discussion in WS2 was more like an informal talk with no strings attached. Moreover, in WS1 the chairman interpreted the arguments of the participants and translated these arguments to concepts and relationships. In WS2, the task of interpretation and translation was fulfilled by the facilitator behind the laptop. The problem with the latter is that, if things are unclear for the facilitator, he or she needs to interfere in the discussion. In the approach of WS1, the diagram on the screen functioned far more as a central focus point. In our experience seems the latter far more effective than having a discussion and meanwhile a facilitator trying to interpret all arguments and putting these in a diagram.

Conclusions

We may conclude that Quasta is considered as a useful tool, which has a low threshold for non-technicians. It stimulates awareness of causal links and dilemmas. Moreover, the tool can be used to explore scenarios qualitatively. In doing so, the approach helps to reveal knowledge gaps. As such, the tool can potentially be used as a first step, prior to multi-criteria analyses (MCA). A workshop facilitated with Quasta results in a list of variables, which can be indicators, measures or goals to be used in MCA. Therefore, we recommend to investigate the opportunities of combining Quasta and MCA.

Acknowledgements

We would like to thank Silja Renooij for her feedback on QPN-related issues, Marek Druzdzel and his Decision Systems Laboratory for allowing us to use QGeNIe as a graphical user interface. The 'Sustainable living in the Dutch coastal zone' project has been supported by the Dutch foundation *Leven met Water*, TNO, the Netherlands Environmental Assessment Agency and other consortium partners. The workshop in Chile was only possible because of Victor Marín as a Spanish-speaking chairman and the support of Elena Ianni in making the diagrams. Finally, we would like to thank all of the participants of the workshops who have taken the efforts to fill in the questionnaire and to answer our questions.

References

- Axelrod, R., 1976. *Structure of Decision - The Cognitive Maps of Political Elites*. Princeton University Press, Princeton, New Jersey, USA.
- Bell, M.L., Hobbs, B.F. and Ellis, H., 2003. The use of multi-criteria decision-making methods in the integrated assessment of climate change: implications for IA practitioners. *Socio-Economic Planning Sciences* 37: 289-316.
- Boogerdt, J.L.M., 2005. *Van Droge Kennis naar Natte Natuur*. PhD thesis, Vrije Universiteit, Amsterdam.
- Bower, B.T. and Turner, R.K., 1998. Characterising and analysing benefits from integrated coastal management. *Ocean and Coastal Management* 38: 41-66.
- Brouwer, R., 2000. Environmental value transfer: state of the art and future prospects. *Ecological Economics* 32: 137-152.
- CENSOR, 2007. <http://www.censor.name/pagev2/news/news-single-view/article/1/censor-pasarelas-symposium-workshop.html?cHash=f7ab6f69bb>. Webpage of CENSOR. Acquired: January 11, 2007.
- Cicin-Sain, B. and Knecht, R.W., 1998. *Integrated Coastal and Ocean Management: Concepts and Practices*. Island Press, Washington D.C.
- Deelstra, Y., Nootboom, S.G., Kohlmann, H.R., van den Berg, J. and Innanen, S., 2003. Using knowledge for decision-making purposes in the context of large projects in the Netherlands. *Environmental Impact Assessment Review* 23: 517-541.
- Dragan, M., Feoli, E., Ferneti, M. and Zerihun, W., 2003. Application of a spatial decision support system (SDSS) to reduce soil erosion in northern Ethiopia. *Environmental Modelling & Software* 18: 861-868.
- Druzdzel, M.J. and Henrion, M., Year. Efficient reasoning in qualitative probabilistic networks. In: (Ed.), proceedings of the *Eleventh National Conference on Artificial Intelligence*, Menlo Park, California, USA. AAAI press.
- DSL, 2006. <http://genie.sis.pitt.edu/>. Acquired: Februari 22, 2006.
- Eden, C., 2004. Analyzing cognitive maps to help structure issues or problems. *European Journal of Operational Research* 159: 673-686.
- Geurts, J.L.A. and Joldersma, C., 2001. Methodology for participatory policy analysis. *European Journal of Operational Research* 128: 300-310.
- Gregory, R. and Wellman, K., 2001. Bringing stakeholder values into environmental policy choices: a community-based estuary case study. *Ecological Economics* 39: 37-52.
- Hämäläinen, R.P., Kettunen, E. and Ehtamo, H., 2001. Evaluating a Framework for Multi-Stakeholder Decision Support in Water Resources Management. *Group Decision and Negotiation* 10: 331-353.
- Hisschemöller, M., 1993. *De democratie van problemen, de relatie tussen de inhoud van beleidsproblemen en methoden van politieke besluitvorming*. VU-Uitgeverij, Amsterdam.
- Hisschemöller, M. and Hoppe, R. (Editors), 2001. *Coping with intractable controversies: The case for problem structuring in policy design and analysis. Knowledge, power and participation in environmental policy analysis. Policy studies review annual*. 12. Transaction Publishers, New Brunswick.
- Hisschemöller, M., Tol, R.S.J. and Vellinga, P., 2001. The relevance of participatory approaches in integrated environmental assessment. *Integrated Assessment* 2: 57-72.

- Hjortso, C.N., 2004. Enhancing public participation in natural resource management using Soft OR -an application of strategic option development and analysis in tactical forest planning. *European Journal of Operational Research* 152: 667-683.
- Holmberg, J., 1998. Backcasting: A Natural Step in Operationalising Sustainable Development. *Greener management international* 23: 30-51.
- in 't Veld, R.J. (Editor), 2000. *Willens en wetens: de rollen van kennis over milieu en natuur in beleidsprocessen*. Lemma, Utrecht.
- Khan, S. and Quaddus, M.A., 2004. Group Decision Support Using Fuzzy Cognitive Maps for Causal Reasoning. *Group Decision and Negotiation* 13: 463-480.
- Kolkman, M.J., Kok, M. and Van der Veen, A., 2005. Mental model mapping as a new tool to analyse the use of information in decision-making in integrated water management. *Physics and Chemistry of the Earth* 30: 317-332.
- Korfmacher, K.S., 2001. The politics of participation in watershed modelling. *Environmental Management* 27(2): 161-176.
- Marchant, T., 1999. Cognitive maps and fuzzy implications. *European Journal of Operational Research* 114: 626-637.
- Mendoza, G.A. and Prabhu, R., 2005. Combining participatory modeling and multi-criteria analysis for community-based forest management. *Forest Ecology and Management* 207: 145-156.
- Özesmi, U. and Özesmi, S.L., 2004. Ecological model based on people's knowledge: a multi-step fuzzy cognitive mapping approach. *Ecological Modelling* 176: 43-64.
- Pearl, J., 1988. *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference*. Morgan Kaufmann Publishers, Palo Alto.
- Ravetz, J.R., 1999. Citizen participation for integrated assessment: new pathways in complex systems. *International Journal of Environment and Pollution* 11(3): 331-350.
- Renooij, S., 2001. *Qualitative Approaches to Quantifying Probabilistic Networks*. PhD thesis, Utrecht University, Utrecht, The Netherlands.
- Robinson, J., 2003. Future subjunctive: backcasting as social learning. *Futures* 35(8): 839-856.
- Soini, K., 2001. Exploring human dimensions of multifunctional landscapes through mapping and map-making. *Landscape and Urban Planning* 57: 225-239.
- Treby, E.J. and Clark, M.J., 2004. Refining a Practical Approach to Participatory Decision Making: An Example from Coastal Zone Management. *Coastal Management* 32: 353-372.
- Turner, R.K., 2000. Integrating natural and socio-economic science in coastal management. *Journal of Marine Systems* 26: 447-460.
- UNEP, 1999. *Conceptual framework and planning guidelines for integrated coastal area and river basin management*, United Nations Environment Programme.
- Uran, O., 2002. *Spatial Decision Support Systems for Coastal Zone and Water Management*. PhD thesis, Free University, Amsterdam.
- van Asselt, M.B.A., 2000. *Perspectives on Uncertainty and Risk - The PRIMA Approach to Decision Support*. Kluwer Academic Publishers.
- van Asselt, M.B.A. and Rijkens-Klomp, N.A., 2002. A look in the mirror: reflection on participation in Integrated Assessment from a methodological perspective. *Global Environmental Change* 12(3): 167-184.
- van Kouwen, F.A., Dieperink, C., Schot, P.P. and Wassen, M.J., 2007a. Applicability of Decision Support Systems for Integrated Coastal Zone Management. *Coastal Management* [Accepted after revisions].
- van Kouwen, F.A., Renooij, S. and Schot, P.P., 2007b. Inference in Qualitative Probabilistic Networks revisited. *Mathematics and Computers in Simulation* [Submitted].
- van Kouwen, F.A., Schot, P.P. and Wassen, M.J., 2007c. Linking advanced simulation models and interactive cognitive maps. *Environmental Modelling & Software* [Submitted].
- Vonk, G., Geertman, S. and Schot, P.P., 2005. Bottlenecks blocking widespread usage of planning support systems. *Environment and Planning A* 37: 909-924.
- Vonk, G., Geertman, S. and Schot, P.P., 2006. A SWOT analysis of Planning Support Systems. *European Journal of Operational Research* 38: forthcoming.
- Vonk, G.A., 2006. *Improving Planning Support - the use of Planning Support Systems for spatial planning*. PhD thesis, Utrecht University, Utrecht.

- Wellman, M.P., 1990. Fundamental concepts of qualitative probabilistic networks. *Artificial Intelligence* 44: 257-303.
- Wellman, M.P., 1994. Inference in cognitive maps. *Mathematics and Computers in Simulation* 36: 137-148.
- WorldBank, 1996. *Guidelines for Integrated Coastal Zone Management*, Washington DC, USA.