Bridging the gaps between design and use: developing appropriate tools for environmental management and policy

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Abstract: Integrated assessment models, decision support systems (DSS) and Geographic Information Systems (GIS) are examples of a growing number of computer-based tools designed to provide scientific decision and information support to people within environmental management and policy organizations. It is recognized that end-user organizations are often not as receptive to using such tools as desired but that little research has been done to uncover and understand the reasons why. As part of the process to understand what tools are used and why, and conversely what tools are not used and why, this paper presents some views on the issues involved. No claim is made regarding the completeness of the issues covered, rather the purpose of the paper is to instigate discussion about how to improve tool design practices in such a way as to benefit environmental management and policy. Conflict between the aims of tool designers to develop usable and useful tools which also contain some degree of technological innovation is highlighted as a potential cause of problems. A call for clarity of purpose in tool design is made to make it clearer both to the designer and the client organization what the main aim of the design process is as a means of uncovering mismatches in expectation. Further, a call is made for designers to move from a technology-push to a demand-pull perspective as a necessary step towards designing more appropriate tools. A range of social dimensions of relevance to tool design are also discussed including the need to involve clients and stakeholders early in the design process, whether a model should present a simple and engaging story and to what extent good science can be implemented through the use of computer models, and the need to build trust between tool designers and tool users as a necessary part of making tools useful.

Keywords: decision support; information support; environmental management; environmental policy; decision support tools

1. INTRODUCTION

Sound decisions in environmental management and policy usually require the examination of alternative solutions (in terms of continuous ranges or qualitatively different options), and may require the consideration of alternative problem formulations prior to option assessment. In this context, formal computer-based modeling techniques can provide a means of structuring and exploring problems, and of generating qualitative and quantitative information for analyzing and characterizing decision spaces. Computer-based modeling technologies consequently have a potentially critical role to play as components of decision and information support tools (DISTs) to informing environmental management and policy processes. In particular, tools such as integrated assessment models (IAM) (Parker *et al.* 2002), decision support systems (DSS) (Courtney 2003) and GIS (Van Lynden and Mantel 2001) have been identified as being well suited to providing support to complex decision processes through fulfilling a number of roles (Van Daalen *et al.* 2002). However there is a recognized gap between the claims made about the usefulness of such tools within the academic literature and their demonstrated utility (Reeve and Petch 1999, McIntosh *et al.* 2005). The question is why, and what, if anything, can be done in terms of

improving tool design for greater usefulness and usability?

To answer these questions we wish to better understand how data, information and knowledge are acquired and manipulated during processes of human decision-making, and how such processes can be augmented and supported through the use of appropriately designed models and software tools.

Bridging the gaps between design and use effectively will not be a simple endeavour and will require consideration of questions including (but not limited to):

- What potential and demonstrated benefits do models and DISTs bring to environmental management & policy?
- What are the major barriers to the uptake and use of DISTs?
- What makes a DIST useful for different management & policy contexts?
- How is information acquired, stored, manipulated and used in different environmental management & policy processes?
- How can models and DISTs be designed to better meet the information and information processing needs of management and policy organizations?
- How can efficient communication be set up between scientists, managers and policy makers for the future development of more effective models and DISTs?

Understanding what constitutes appropriate tool design will require answers to these and potentially many more questions. With this paper we shall try to make some progress through setting out some of the issues involved and by suggesting some of the design research and practice routes which may be profitable to pursue. First we will focus on clarifying the purpose of designing DISTs, and in doing so we shall be calling for a change in emphasis from technology-push to demand-pull design perspective. Second, we will focus on identifying and discussing the implications of some social dimensions for tool design. Finally we shall conclude with a summary of the major issues raised during the paper.

2. WHAT ARE WE TRYING TO DO – CLARIFYING DESIGN AIMS

As researchers, scientists and tool designers we are often trying to fulfill a range of potentially conflicting agendas. For example, we may be trying to innovate methodologically or technologically and at the same time be trying to transfer scientific knowledge directly into management or policy use through designing a decision or information support tool. Can we hope to effectively fulfill multiple agendas? Does having a focus on generating technological innovation preclude the design of usable and useful DISTs? Are we trying to satisfy too many constraints and objectives and in the process reducing the usefulness of the tools we produce?

Certainly the danger in treating technological ‘means’ as ‘ends’ is clear. We, as a community of researchers, should be clearer that our DISTs and information technologies are the means by which we hope to achieve our common end - improved environmental management and policy. However this end can sometimes be obscured by the needs of other agendas, particularly generating technological or methodological innovation.

Of course we should invest effort in improving our tools and technologies and this will involve focussing on developing our means. But in doing so we should take care not to lose sight of our main end or we risk becoming locked into what Marx termed the ‘fetishism of the product’ – the development of technologies (or products) for their own sake (Reeve and Petch 1999). Such fetishism inevitably results in a technology-push perspective to tool design where technologies are developed and literally pushed out towards potential clients irrespective of their actual needs (whether stated or not). Within the innovation and technology transfer literature this strategy is recognised as being inadequate (Seaton and Cordey-Hayes 1993).

We should also take care not to confuse the development of new types of tool or improved versions of tools with the design of tools to be directly used by other people in environmental management and policy organizations. Developing DIST technology is a perfectly legitimate and valuable activity but we should not pretend that in doing so we will end up with usable and useful tools for other people. Pushing technologically innovative but inappropriately designed information systems is a strategy that has come under strong criticism (Checkland and Holwell 1999). Indeed, such authors have argued that you cannot claim to have designed a tool to support the activities of people in (environmental management and policy) organizations without first understanding what it is that those people collectively do (organizational action) and how organizational performance is measured. That is to say it is not possible to design a tool to be used by people in organizations without first understanding

the demand for information and information representation, manipulation, communication and storage facilities, and without understanding what constitutes organizational effectiveness and efficiency i.e. how organizational performance is measured. In other words we need to move towards a demand-pull design perspective in our work (Reeve and Petch 1999).

DISTs can of course be designed to fit with an alternative way of working and the development of a DIST can in this sense be seen as part of a broader process of organizational change. But clearly if this the case, then both managers and operational level employees must have agreed before the tool is designed, and ideally should be involved, for the process of changing organizational action cannot be achieved without them. Further, DISTs cannot be designed to fit a new form of organizational action if nothing is known about it. Involving the 'end-user' intimately is absolutely necessary under such circumstances.

One of our concerns is that DISTs are often not designed to support what people in (environmental management and policy) organizations currently do. Rather, they embody an implicit argument for change in action. It should not therefore be surprising in such cases that the tools concerned are not used – they can't be (or at least not without the necessary organizational change).

To help avoid agenda conflicts or confusion between supporting and changing organizational action we think environmental DIST designers would benefit from clearly stating their aim for each tool to be designed:

1. To be used by the people designing the tool as a research or consultancy service, or;
2. To be used by people in an external, specified end-user organization to support:
    a. existing forms of organizational action through providing currently used information in a more efficient way, or;
    b. existing forms of action through providing new information in such a way that it is hoped the effectiveness of organizational action will be improved, or;
    c. an alternative form of organizational action through providing new information in new ways, or;
3. Not to be used routinely at all but to demonstrate some methodological or technological advance.

The aim of designing a tool partly determines the way in which the tool should be developed. Design aims 1 and 3 above require little consideration of how people other than the tool designers work. Under such circumstances there are no strong pressures to use one design or development method over another, except that it must suit the design team.

This is not the case with design aim 2. Here it is absolutely crucial to understand the system that is to be supported (people collectively acting in an organizational setting) before the system that supports (the DIST) can be designed (Checkland and Holwell 1999). Design under these circumstances must be demand-pull in orientation and may have to use 'socio-technical' methods like Soft Systems Methodology (Winter *et al.* 1995) during the development process to characterize and better reflect organizational needs in tool design.

2. SOME SOCIAL DIMENSIONS OF RELEVANCE FOR TOOL DESIGN

In developing models and DISTs to support environmental management and policy, distinguishing between end-users, stakeholders, and clients may be helpful, since each audience has different interests in the modeling process. End-users are a person, group, or corporate entity who modelers think might be informed or gain knowledge from a model or DISTs. End-users are those who can learn something from a model by actually using it, as opposed to a stakeholder who has a direct interest in the policy and planning processes. Stakeholders are people affected by the decision in question - policies adopted or plans created to resolve a particular environmental management action or issue. Stakeholders sometimes get modeled as actors or agents. As a minimum, stakeholders are connected with model outcomes as much as the latter contribute to the decision making process. The client for a model or DIST usually has a financial interest in the modeling or software development. The client may be interested in resolving a conflict between stakeholders, have stakeholders as its constituency, or be the end-user him/herself or a consultant to the policy and/or planning process associated with environmental management.

End-users, stakeholders, and clients have different experiences and are important for both generating information and building knowledge for the modeling process. These groups, because of their interest as end-users, involvement as stakeholders, and management as clients tend to bring more local and specific information and knowledge. The information and knowledge of end-users,

stakeholders, and clients can be very helpful in informing model agenda (or boundary) setting, identifying the end states of concern, and designing the structure of a model. Model and DIST developers benefit from understanding social activities and agendas that end-users, stakeholders, and clients identify.

Timely involvement of potential end-users and stakeholders: Often in modeling environmental management and policy processes end-users and stakeholders are brought into the modeling process too late. Part of the reason for late involvement is the desire to get the modeling as fully developed as possible and representing reality as accurately as possible. The result is that perfecting the model takes too much project time and budget.

Involving end-users, stakeholders, and clients, however, heightens social and modeling tradeoffs about system completeness, questions how much complexity and realism to include in a model, and affects the allocation of project resources.

The early involvement of the end-user community in model and DIST development raises the issue about the re-usability of tools. Should tools be developed from scratch in any new application case? The theoretical answer is clearly negative, but the identification of effective best practice guidelines for tool design and re-use is far from having being defined.

Policy and management vs. research timescales: Research and decision making in most cases follows quite different time-lines and scales. A researcher can improve the model almost eternally, while decisions are likely to be made within years, or even months. Political bodies are mostly concerned with specific times of not more than 2-3 years, after which they will undergo reelection and it will be too late for them to employ improved modeling results. Researchers are often unprepared to meet such deadlines.

It takes certain courage to take responsibility for the results that we foresee, even though we know there is considerable uncertainty involved. Is it better to err based on the bulk of knowledge and expertise provided by science, or to shy away from recommendations because we are entirely sure that they are 100% correct?

More emphasis on the social dimensions of actors: The terminology of end-user, stakeholder, client, agent, and actor connotes an individual and does not suggest thinking in terms of how people organize socially. Agent-based modelers invest extensive effort in creating realistic actors. Benenson and Torrens (2004) identify nine characteristics of actors in agent-based models. Actors are *reactive* and respond to their environment. They are *autonomous* and control their own actions. Actors have *goal-oriented* responses to the environment. Actor behaviors are *continuous* in time, and actors are *communicative* with other actors, even evolving language. Making actors *mobile* and *flexible*, too, are important dimensions. The ability to *learn* based on experience is a human characteristic included in actors. Finally, actors have *character* with a believable personality and emotions. Yet no mention is made about actors being social, interacting in groups, basing choices on observation of others, or building support for particular value positions.

Policy and planning processes usually involve competing choices. Very often one set of stakeholders or group gains while another loses opportunities. Thus, the model or DIST needs to evaluate benefits to groups of actors. More important, however, is that people are inherently social (Kempton 1995). They live in families, organize in groups, form communities, band together to support or oppose policies, follow the example of their neighbors, accept the lead of people they admire and respect. Tool design and use can be improved through better understanding of the social processes to be included in models and more importantly, in thinking about the social dynamics needed to build models.

The role of modelling science in decision making – information and communication: The assumption that science is an important part of decision making may not be supported in practice. For example, US social science research shows the public woefully uninformed, and getting a large portion of their information by word-of-mouth (NSF 2006; Steel et al. 2006, 2003; PNCERS 2000; Wright and Shindler 1999; Beder 1998). Often a good narrative is more engaging and useful than the best science (Checkland and Holwell 1999). Is a successful model one that can generate a good story? Models tend to rely on scientific information and not on narratives. Therefore, at least the interface with the end-users, if not the entire model development itself, should try to conform to the preferred communication systems of targeted end-users.

To what extent our attempts to make the models "better" and as a result, more inclusive and therefore complex, actually make them less useful to communicate with the public and positively contribute to decision making? Should we be building simple qualitative models based on complex detailed studies as devices to inform management and policy? These are easier to

explain and communicate to clients, stakeholders and the wider public.

For example, take the positive feedback associated with global climate change - melting ice leads to decreased albedo which leads to higher temperature which in turn results in more melting ice or the permafrost thawing in Siberia and so on. Higher temperatures would cause more bogs to thaw resulting in more CH_4 release, an enhanced greenhouse effect and in turn yet higher temperatures. These are simple systems models that are much easier to communicate than GCMs. Could we achieve better results using such communication tools? The obvious issues here are about how to simplify the inherent complexity of socio-environmental systems, how to incorporate uncertainty into such models without compromising simplicity and efficient communication, and whether simple models can be used at all to inform one-off decisions or more routine management processes, or whether they are simply mass communication devices.

Think educational opportunities: It is generally recognized that models are first of all learning tools for scientists, teaching modelers much about their own assumptions, lacks of knowledge, etc.. But models and DISTs containing models can be valuable educational tools also for a broader public. When models broaden perspectives, they can have important information generating and knowledge informing roles as well. Models can be used to conduct and evaluate social or ecological experiments and do analyses that are not possible in actual socio-environmental systems. Thus, one important class of end-users is students and the general public who can learn about biophysical or social processes through interaction with models.

Creating a common language is critical in an interdisciplinary modeling process, but the language development and communication process usually takes longer than expected and it should, therefore, be adequately planned.

Validating models – credibility and trust: One of the difficult tasks in socio-environmental modeling in support of management and policy is validating models. Validation is a process of determining whether the model representation of policy and planning processes match those of real systems and provide real assistance in thinking about the biophysical and social issues involved.

In the policy context, validation may be less about the quality of the science and more about the credibility and trust that end-users, stakeholders, and clients have of the model and for the modelers. Trust may be thought of as alien to the representation of scientific processes, but trust is critical to getting any of the populations served to accept its value to management and policy. Associated with trust is people's intuition about how the world works. Models and tools that seem reasonable will be more likely to adopted by end-users, stakeholders, and clients and thus influence policy making. How much a model can be considered "reasonable" is obviously biased by the knowledge and skills of interested people, but also by their own interests: "I'm ready to buy only the model supporting my preferred answers" – one water manager.

From the above the development and uptake of science embedded in models and DISTs by potential end-users, clearly appears as an iterative process of mutual learning.

3. CONCLUSIONS

Computer models and the decision and information support tools that rely on them are a relatively new technology within environmental management and policy despite the fact that they have been used within academic science research for many years. Attempts to tailor models and tools to suit management and policy contexts have not been entirely successful to date and there is a reasonable case to be made that environmental modeling and DIST development practices need to change if the technology is to improve environmental management and policy. Part of the required changes will come from refocusing our design perspective from technology-push to demand-pull, and partly from taking into account a wide range of social dimensions concerned with how to best include and involve clients, stakeholders and the general public.

Effective communication and information management appear to be the first prerequisites for bridging the gaps between design and use of models and DISTs. The second fundamental prerequisite that should not be forgotten is the existence of a real willingness to contribute to improved policy and decision making processes, both from science and policy sides. Once the existence of such prerequisites has been assessed, a mutual learning process could be established between model and DIST designers and policy makers.

We hope that the environmental modeling and software community can play an active role in instigating, discussing and implementing such processes and required changes to current practices.

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