Decision Support Systems for Integrated Environmental Management: Anticipating and Interrogating Bias

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Abstract: This paper argues that an unreflexive approach to the design of environmental Decision Support Systems (DSS) may serve to undermine effective Integrated Environmental Management (IEM) by running counter to the participatory and transparent policymaking which IEM promotes. The paper explores the potential for bias in environmental DSS, and proposes a taxonomy of bias and a framework for anticipating or interrogating bias. Preliminary insights are discussed which have emerged from a case study application of the framework to a project which is developing a DSS to assist IEM in the highlands of Northern Thailand.

1. INTRODUCTION

Through policies aimed at implementing the Rio Declaration, Agenda 21 and related conventions, many governments have formalised their commitment to a sustainability paradigm. However, the operationalisation within public policymaking of the principles of sustainability, and its managerial adjunct Integrated Environmental Management (IEM), has proved challenging. Legislative demands and political pressures are requiring environmental decision-makers to undertake increasingly rigorous analysis to support and validate decisions[1]. Monitoring, processing, assessing and analysing larger quantities of complex information, often within shorter time periods and more constrained financial resources, poses significant difficulties even to a professional decisionmaker. Reconciling the demands for more comprehensive, integrated and informed decisionmaking with a participatory approach involving more local stakeholders presents an even greater challenge.

In recent years, technocracy has promoted the development and application of computer-based Decision Support Systems (DSS) to resolve the operationalisation dilemma. Following Simon (1973), a DSS is defined as a computer-based system which is aimed at helping decision-makers cope with ill-structured problems.

There are three principal dimensions to the conventional rationale for DSS. Firstly, it is argued that computer-based tools may enable a time-constrained decisionmaker to enhance their natural computational power and thereby facilitate consideration of a wider range of variables. Secondly, DSS is perceived to allow victory over ignorance by enabling a non-expert decisionmaker to undertake specialist analysis which they might otherwise be unable to perform due to a lack of the appropriate skills, knowledge or experience. Thirdly, advocates argue that DSS leads to greater objectivity.

On the surface, DSS appears a godsend in terms of enabling decision-makers to cope efficiently with the demands of sustainable development. As Walker and Johnson (1996:175) comment, addressing the utility of DSS to assist Total Catchment Management in Australia, "it is hard to see how increasingly demanding objectives in environmental management could be achieved without effective and efficient use of information technology tools". But how useful is DSS to assist IEM in terms of supporting the participatory, integrative and transparent policymaking which IEM philosophy promotes?

According to the conventional paradigm of DSS development, informations systems and other scientific experts iteratively design and customise a DSS for user clients. Active participation by stakeholders other than the clients in the design process is rare. This paper challenges the assumption that the conventional approach yields innately objective, expert decisions. Instead, it is argued that bias is an inescapable feature of DSS, and if DSS is to effectively assist the operationalisation of the principles of IEM, a reflexive approach to the design, development and implementation of DSS, which recognises the potential for bias, should be encouraged.

2. EMBEDDED BIAS IN DECISION SUPPORT SYSTEMS

Claims of objectivity are derived from the scientific basis of DSS. As Ozawa (1996:221) comments, "Science is conceived as a process that yields an objective, rational, politically neutral body of knowledge". However, numerous analyses from the sociology of scientific knowledge have demonstrated that the technical construction of scientific logics is necessarily shaped by either implicit or explicit social mechanisms of closure endemic to the culture of the observer (for example, Wynne 1992). In the context of environmental DSS, theory of the social construction of knowledge implies that the knowledge embodied within the technology (the formulation of the problem, the data selected as relevant, the theoretical models favoured, and the options or what-if scenarios permitted by the system to be modelled) will reflect, perhaps inadvertently, normative codes and interests which arise from the values, priorities, experience and organisational culture of those who have input into the design or development of the technology.

Environmental management concerns are seldom unpoliticised. Instead, normative and political pluralism tend to result in multiple and competing definitions of environmental problems and their attributes. As Segal

[1] For example, Chapter 8 of Agenda 21 discusses the need to improve the use of data and information at all stages of planning and management, to make systematic and simultaneous use of social, economic, developmental, ecological and environmental data, and to adopt comprehensive analytical procedures for prior and simulataneous assessment of the impacts of decisions (UN1992:65).

(1994:7) notes, "Because of its inherent contradictions and elusiveness, the public interest can never be defined technologically". Consequently, a DSS designed to address a particular environmental problem, at a particular scale, or within a particular boundary will tend to be tailored to and therefore to favour the world view of those who participate in its design. Where the construction of the technology systematically influences the output of the technology, we may conceptualise bias as having been embedded into the structure of the technology.

A key source of embedded bias arises from the limitations of the models incorporated within the system in representing complex, dynamic ecosystems. In describing environmental phenomena, a modeller attempts to abstract salient trends and patterns from a complex tangle of information (Malayang 1996). The model thus represents an abstraction of selected elements and relationships within the ecosystem; the full spatial and temporal complexity of the ecosystem is not able (nor intended) to be represented. The task of translating scientific knowledge to a computer-based DSS may necessitate further abstraction, as attempting to incorporate all known parameters is invariably time consuming, requires vast processing power and may introduce uncertainty due to unforeseen interactions between variables. Any abstraction necessitates discretionary judgments on the part of the researcher. Clearly, which knowledge is included as well as which knowledge is excluded will influence the output of the technology, and may therefore be conceptualised as a form of embedded bias.

Given that a computer-based model essentially comprises a set of mathematical relations, then the descriptions of environmental phenomena embodied within that model are invariably influenced by the ease of representation of those phenomena in calculable, quantifiable variables. Variables less amenable to computational treatment, such as intrinsic significance, cultural traditions or political motivations, are invariably suppressed. The systematic non-incorporation of certain variables represents a crucial case of embedded bias through absence of knowledge. Increasingly, modellers are attempting to cope with this limitation by developing methods of quantifying qualitative variables or formalising human constructs. However, this tends to introduce further bias where the representation of these variables is inadequate, cursory, simplistic or misleading. Following Smithson (1989:7-10), we may conceptualise this as embedded bias due to the distortion of knowledge.

A further example of distortion of knowledge may emerge when either novelty or surprise lead to new or altered societal knowledge. In focussing on ill-structured rather than simple, bounded problems, DSS aims to support a dynamic, evolving decision environment. Consequently, DSS is often based on a toolkit philosophy whereby users can select and link up relevant databases, models and visualisation systems as required. Despite this approach, limitations remain in terms of coping with novelty. Once resources have been invested into the construction of a particular technological system, it may be costly to make substantial changes. As a result, it may not be possible to subject a technological system to the same rate of modification as the refinement of a theoretical construct.

3. INEQUALITY OF ACCESS AS BIAS

Another form of bias arises when the use of DSS limits the opportunities available to certain stakeholders to participate in decisionmaking because of inequalities in access to the technology. Firstly, consider the location and cost of a system relative to a user's location and financial resources. In the case of an expensive, centrally located system, access would be limited for potential users who live in remote areas and have limited financial resources at their disposal to fund travel or compensate time away from productive work. However, these constraints may be alleviated if a terminal, from which the central system may be accessed, is provided to the remote user. Even if a DSS is set up such that remote access to the system is available, access to the information might still be constrained if the conventional or computer literacy required to use the system is greater than that of the user. In response to this problem, DSS developers are increasingly placing an emphasis in user interface design on intuitive natural language dialogue facilities and visual presentation of system responses which are comprehensible to all users (Mikolajuk 1996:10).

However, even if the user-friendliness of a system is sufficiently high for a user with a low degree of computer literacy to use the technology, inequities in terms of access to information may still be introduced, if awareness and comprehension of embedded assumptions are not consistent across users. If a user lacks sufficient traditional, scientific or computer literacy to understand how variables within the system translate to the real world problem, and to appreciate how embedded assumptions may influence the system output, then their capacity for informed participation is clearly limited.

Political factors (such as hierarchy and gender biases) will create differences in the extent to which different actors participate in environmental policymaking. Where these differences exist independent of the introduction of DSS, then they may be considered irrelevant to a taxonomy of bias for DSS. However, pertinent bias emerges if the application of DSS introduces or exacerbates differences in political power or will, or subsumes or supercedes alternate avenues of participation. To illustrate the latter case, consider an actor who wishes to participate in environmental policymaking but who is unable to use, uninterested in using, or unwilling to use DSS. If the DSS has subsumed or superceded alternate avenues of participation previously open to that actor, then the introduction of the technology has effectively limited the actor's opportunities to participate in policymaking.

4. TAXONOMY OF BIAS

Drawing on Smithson's (1989:7-10) taxonomy of ignorance, Table 1 proposes a taxonomy of bias relevant to the design and use of DSS. Three sources of bias in terms of the output of the technology are identified: embedded bias; incomplete knowledge; and distorted knowledge.

Embedded bias arises from conscious or unconscious judgements which influence design, such as which models or data should be incorporated, or the framing of either the problem or the options available to resolve the problem. Incomplete knowledge and distortions in knowledge are associated with ignorance, particularly in terms of coping with complexity and novelty. Incomplete knowledge encompasses absence of knowledge (such as the nonaccommodation of qualitative factors or human constructs), and the noncommunication of the uncertainties in knowledge. Distortion of knowledge encompasses inaccuracy (distortion in degree) and confusion (wrongful substitution in kind) of knowledge and includes the inadequate quantification of qualitative factors and inadequate random number generation. Four sources of bias in terms of access are identified: the geographical location of the technology; the financial cost of use of the technology; the literacy required to use and understand potential biases in the output of the technology; and political considerations.

Failure to recognise the potential for bias in DSS may undermine participatory and transparent policymaking. Meanwhile, failure to recognise an inherent bias in DSS in favour of quantitative factors and easily modelled processes, while neglecting qualtitative factors and sociopolitical processes, may undermine the integrated, interdisciplinary approach to policymaking which IEM promotes.

Table 1: Taxonomy of bias associated with the use of DSS

Biased output:
Socially embedded bias (conscious or unconscious)
Commitment to a particular system
Commitment to particular system components
Commitment to the logics underpinning the system
Incomplete knowledge
Absence of knowledge
Noncommunication of uncertainties
Distortion of knowledge
Confused knowledge
Inaccurate knowledge
Biased access:
Geographical considerations
Central location vs network
Financial considerations
Cost of purchasing or establishing the system
Cost of ongoing use of the system
Literacy
Literacy required to use the technology
Literacy required to appreciate potential biases
Political considerations
Technology introduces/exacerbates differences in political power or will
Technology subsumes/supercedes alternate avenues of participation

5. DSS AS CONDITIONAL EXPERTISE

If the knowledge embodied within DSS is considered as a reflection of social networks and identities, then the 'expertise' of a particular system is dependent on the 'expertise' of those who have input into its development. Within the conventional paradigm of DSS development, the question of whether a DSS provides an inherent source of expert authority thus rests on the question of whether science provides an inherent source of expert authority.

Positive responses to the latter question generally derive from two principal, alternate rationales. Firstly, despite recognition of the conditionality and subjectivity of scientific knowledge, science is still portrayed by many as certain and objective, particularly away from the research threshold (Collins 1987:692). Secondly, some policy actors, although cognisant of critiques of scientific knowledge, maintain that science provides the most reliable, realistic picture of the natural world. Two important corollaries to the reification of scientific knowledge as unrivalled expertise are: firstly, a tendency for alternate bodies of knowledge to be dismissed as inferior; and secondly, a broad anxiety amongst some policymakers and scientists about the community's inability or irrational unwillingness to accept 'correct' scientific information. The latter perspective suggests that public distrust of scientific knowledge stems from stoic ignorance.

However, Wynne (1992) and others have demonstrated that scientific knowledge (as well as the technology which embodies that knowledge, institutions which promote that knowledge and decisions made on the basis of that knowledge) may suffer a public loss of credibility if the community perceives that the 'expert' knowledge is irrelevant to or incompatible with the policy problem. This often arises due to a public perception that scientists have made incorrect or overly simplistic assumptions about complex, diverse local environments such as inappropriate standardisation of environmental variations or resource use.

Meanwhile, cases from adaptive management have illustrated how empathetic or local knowledge may assist in managing scientific distortion or ignorance and thereby may enrich a scientific description. As Funtowicz and Ravetz (1991:149) comment: "Knowledge of local conditions may not merely shape the policy problems, it can also determine which data is strong and relevant... Those whose lives and livelihood depend on the solution of the problems will have a keen awareness of how general principles are realised in their 'back yards'".

Drawing on Chambers (1997), a key question is 'Whose definition of expertise counts?' Challenging the notion of self-proclaimed and un(der)validated expertise, cultural theorists argue that public knowledge should be evaluated and validated as part of the social system that creates and sustains it (Rayner 1992:98). A similar theme is discernible within public policy, risk analysis, adaptive management and rural development discourses (McLain and Lee 1996:439, Torgerson and Paehlke 1990:9, O'Hara 1996:99).

What insights do these perspectives on expertise offer in terms of improving the capacity of DSS to promote more transparent, accountable and participatory policymaking?

They suggest that if DSS is developed only by an elite technical or epistemic group according to the conventional paradigm then assumptions and uncertainties should be open to scrutiny by the community of interest. Some DSS, such as RAISON, are now promoted as featuring the capability for users to gain access to underlying assumptions such as technical details about models, the rule base and how inferences were made (Lam et al 1994:512). A limitation of this approach is that some assumptions, such as those due to ignorance or tacit normative codes, will be hidden from the developers and may therefore be difficult for them to communicate.

An alternative is a more participatory mode of DSS design, development and implementataion in which only knowledge already validated by the community of interest as relevant and credible be incorporated within the DSS.

6. PARTICIPATORY DEVELOPMENT OF DSS

Participatory development of scientific models has been a recurrent albeit infrequent theme since the 1970s. For example, Straus (1979:663) advocated a discursive process for model design, involving data mediation and participatory model building, as a means to expose normative assumptions embedded within the model and thereby better manage complexity: "The very act of trying to seek agreement on the data, and to build the model... will force us to better understand the viewpoints of our opponents and, conversely, help our opponents understand our viewpoint and, if performed with integrity and intelligence, it should improve predictability and accuracy". According to this perspective, echoed throughout adaptive management literature, a participatory approach may provide a forum for stakeholder learning, as well as assisting in managing for bias and thereby enhancing the quality and the credibility of the DSS.

While a participatory approach may appear an improvement on the conventional paradigm, there are significant limitations. On the one hand, logistical and financial constraints obviously preclude the participation of all stakeholders from the genesis of design. On the other, given the personal costs of participation, many stakeholders may elect not to participate. Also, it is not possible to identify and therefore to seek the participation of any future stakeholders who may later develop an interest in the problem.

A further limitation may arise from the policy of funding bodies which prescribes specification of a project before an application for funding will be approved. Consequently, prior to the commencement of a project aimed at developing a DSS, decisions must be taken regarding such issues as who will be involved in the project, and what types of hardware, software and data will be incorporated. These decisions affect the extent to which development of the DSS may be participatory.

7. FRAMEWORK FOR ANTICIPATING AND INTERROGATING BIAS

Recognising the potential for bias and ignorance within DSS and also the barriers to participation, where does this leave the development and application of DSS to assist IEM? While a few authors have expressed moderated critiques of the conventional paradigm of development (Angehrn and Jelassi 1994:269) or supported a new paradigm emphasising participation and learning (Bellamy 1996:372,389), constructive alternatives have been less forthcoming.

A key area for further research is the development of criteria for assessing and comparing the usefulness of DSS versus existing and alternate decisionmaking processes and tools in terms of assisting IEM in a particular application context. Procedures are also required which assist developers or users committed to or potentially affected by a particular DSS application to explore potential and existing biases associated with the DSS. To this latter end, Table 2 proposes a generic analytic framework based on the taxonomy of bias which is intended to structure an interrogation of potential and existing biases associated with an environmental DSS. The framework is designed to stimulate reflection and discussion on the extent to which an existing or proposed DSS is (or should be) equitable, transparent, participatory and integrative given the objectives and constraints of a particular context.

The framework is divided into three sections: a background section which situates the analysis within a specific context; an interrogation of embedded bias; and an interrogation of biased access. For any application, it is likely that certain questions proposed may be deemed irrelevant or conversely inadequate. Thus the framework will need to be modified to suit a specific application. Accordingly, this framework is not intended as a prescriptive methodology, but rather as a flexible guide.

If applied early, the framework may facilitate the anticipation of biases, thus allowing the management of potential biases before they emerge as problems. If reapplied iteratively throughout the design, development and implementation of the DSS, it may provide a (partial) history of the rationale underlying design, development or implementation decisions, thus facilitating a more transparent process. This may prove useful where a participatory approach is limited, allowing scrutiny after the fact of the underlying logic and assumptions.

The framework is currently being tested and refined through application to a joint Australian National University - Royal Project Foundation of Thailand (ANU-RPF) project which, among other objectives, aims to develop a DSS to assist IEM in the highlands of Northern Thailand. Following two years of preparation, the ANU-RPF project will officially commence research activities in September 1997. The ANU-RPF project has four research components: biophysical, sociocultural, economic and decision support. A number of Thai and Australian researchers from each component are participating in development of the DSS. It is also intended that stakeholder representatives be invited at a future date to participate, but the timing and character of participation remains unresolved.

The three Australian leaders of the biophysical, sociocultural and decision support components agreed to

Table 2: Framework for anticipating and interrogating bias in DSS
A: Background to the application context
A1. Why was this development of DSS initiated? (eg research, technology transfer, greater efficiency etc)
A2. What decision problem(s) is the DSS intended to support?
A3. How might this problem change over time?
A4. Who are the stakeholders to this problem?
A5. Describe the existing policymaking processes relevant to this problem.
A6. Who are the intended users (direct and indirect) of the DSS?
A7. What benefits are these users expected to derive from use of the technology?
A8. In the light of (A2,A6 and A7), what are the information requirements of the technology?
A9. Will the DSS be applied in conjunction with any other policy mechanisms?
A10. What are the criteria for success of the DSS?
B: Embedded bias
B1. Describe the people who are intended to be involved in development of the DSS. Why will they be involved? When will they be involved? How will they be involved?
B2. Describe those stakeholders who are not intended to be involved in the development of the DSS. Why won't they be involved?
B3. Will different stakeholders views be considered during the construction of the DSS or incorporated in any form? If so, how?
B4. How will the decision problem be framed? Who will frame the problem? What alternate ways are there of construing this problem?
B5. How rapidly and easily will the DSS respond to changes in the decision problem or application context over time?
B6. Describe the hardware, software, models and data sets which are anticipated to be incorporated in the DSS. Why will they be incorporated? How will they be integrated?
B7. Have any hardware, software, models or data set options previously under consideration been rejected? If so, why?
B8. What uncertainties and assumptions (including constraints and boundary conditions) are associated with the underlying processes or system components?
B9. How is it intended that the output of the DSS be presented to the user?
B10. How is it intended that uncertainties and assumptions related to the output, underlying processes or system components be communicated to users?
C: Biased access
C1. What is the intended geographical structure of the DSS? (eg. centrally located vs networked)
C2. Compare the location of potential users relative to the DSS.
C3. What are the likely up-front and running costs of the DSS? Who will bear these costs?
C4. Compare the costs of the DSS to the financial resources available to potential users of the system.
C5. What degree of conventional or computer literacy is (likely to be) required to use the system?
C6. What degree of conventional or computer literacy is (likely to be) required to analyse potential biases in the system output?
C7. Compare the literacy requirements of the technology to the literacy levels of potential users.
C8. How will the DSS articulate with existing or intended policymaking processes and institutions? (e.g. is the DSS intended to supplement or supplant policymaking processes; is the DSS likely to empower, disempower or have no effect on policymaking institutions?)
C9. In the light of (A5) and (C2,4,7,8), is it likely that use of the DSS will improve the access of any individual or group to policymaking relative to the existing situation?
C10. In the light of (A5) and (C2,4,7,8), is there a risk that use of the DSS will worsen the access of any individual or group to policymaking relative to the existing situation?

participate in a practical application of the framework. Other researchers in the Australian team have yet to be officially appointed. Part A of the framework was applied during May 1997 according to action research methodology. Each participant completed a questionnaire corresponding to the questions in Part A, then the participants met to discuss their responses in a group discourse. To keep costs of participation in terms of time to a minimum, the group discussion was limited to an hour. Although intended primarily to situate analysis, Part A also revealed how the framework may facilitate group learning. For example, although one participant was familiar with the broad policymaking environment ("fragmented decisionmaking by different departments; (conflicting) top-down impositions of policy/practices on villagers; business... having relative freedom in laissez-faire political context"), the participants were generally unsure about the nature of the specific policymaking processes that the DSS was intended to support, including whether there were any existing processes by which local communities could give input into decisions. As one participant remarked, "this is an important question if we are talking about decision support and raises a gap in our project planning... it is important to know how the DSS can be integrated into the policymaking process if the system is to be more than just a computer".

During the discussion, participants highlighted the importance of the manageability of the project, the need to direct greater attention to identifying the different characteristics of users, finding appropriate ways of interfacing with indirect users, and reflecting further on how the DSS should articulate with other policy mechanisms. In the context of the latter issue, one participant commented, "I'd prefer it to be subsidiary, adjunct to the participatory stakeholder process, not to dominate it".

Part B of the framework was applied during July 1997. For Part B, methods were altered in order to stimulate greater debate. Each participant completed a questionnaire corresponding to Part B, then these responses were collated into a single handout. The group discourse explored how the design and development of the DSS might be improved in the light of the collated responses. In particular, participants were asked to reflect on whether any of the identified problems or biases might put at risk any criteria for success or advantages of the DSS, or conversely which might make more likely any of the potential disadvantages of the DSS, which had been identified during Part A.

During discussion, participants raised several problems, biases or concerns about the DSS. These included: "How can we reconcile a participatory process with manageability?"; "If we accept all stakeholders have the same rights of access to different levels of the DSS, won't we be entering into endless cycles of needs and demands?"; "The DSS can't model or include everything so how can we explain to people the limits on interpreting results?"; and "Will a top-down process corner the DSS?". These concerns suggest recognition of limits to participation, biases likely to be embedded within the DSS, and the politics which surround environmental decisionmaking.

Participants are currently discussing the potential problems and biases, as well as possible strategies of coping with them, with their Thai counterparts. It is anticipated that Part C will be applied in October 1997. With a view to illuminating different cultural attitudes to decisionmaking, other future research will compare Australian participants' responses with the responses of their Thai counterparts.

8. CONCLUSIONS

The technocratic perspective that DSS may provide innnately objective, expert solutions is naive when confronted with the complexity, ignorance and politics which pervade modern environmental management. So long as DSS development remains in the hands of an elite technical or epistemic group, the knowledge embodied within the system, the system structure and the transformed knowledge (output) of the system will tend to conform to and reinforce the biases and ignorance of this group. While opening the development process to a wider cross-section of stakeholders may assist in managing for bias and ignorance, the limits to and costs of participation dictate the necessity of approaches which recognise that bias is arguably impossible to avoid. Rather than viewing bias as a threatening and negative concept, the framework described in this paper utilises the concept of bias to facilitate critical reflection on the extent to which a DSS may support participatory, integrative and transparent policymaking in the light of resource and other constraints.

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