

What is meant by “decision-making” in the context of eco-informatics?

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Introduction

The central goal of the BDEI3 Workshop Report is to define a research agenda for eco-informatics and decision-making. In order to do this, it is important to first define or articulate what “decision-making” means in the context of eco-informatics.

An initial starting point might be to consider the definition provided by Harris (1998): “Decision-making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker.” In the context of eco-informatics, the decision-maker might be a policy-maker (e.g., a politician) or one of his or her analysts, a public agency official managing or working within some environmental program (e.g., a public employee in the U.S. EPA, U.S.D.A. Forest Service, or a state or local agency), a manager or staff in a non-profit organization such as the Nature Conservancy, a citizen environmental advocacy group, employees in a private firm involved in some environment-related decision, or even “citizen scientists” interested in a particular environmental problem or issue. Decision-making processes in the context of eco-informatics (and this report) involve any of these actors or combinations of the above, such as in the context of a town meeting or a public comment period, for example.

Decision-making processes in the public management literature

Over the years, there has been much debate on how to accurately describe decision making processes in general. Beyond an implicit agreement that decisions are made through some sort of process, chaotic or otherwise, there is little else scholars agree upon. Given that much of the decision-making in eco-informatics involve public sector agencies, this review will focus on decision-making primarily in this sector.

Rainey (2003: 160-169) summarizes variations on four major approaches to decision making found in public management literature, none of which is uncontested:

1. The “*Rational Decision-Making*” approach. This view of decision making suggests that decision-makers follow a specific process where goals are decided upon, alternatives are developed in accordance with such goals, and then “the most efficient” alternative is implemented (Baker, et al. 2002; Rainey, 2003; Kingdon, 2003). Stone (2002: 377) refers to these approaches as following a “conveyor belt” process. Rainey (2003: 161) provides a hypothetical example where an organization needs copying machines. A report on three vendors supplying identical machines is developed. The report is reviewed by a manager and the least expensive is chosen. As Rainey states, to choose another vendor “would invite others to question the [manager’s] competence, ethics, or sanity”.

2. The “*Contingency Perspectives Decision-Making*” approach. Some scholars assert that rational decision-making can only occur under “stable, clear, simple conditions” (Rainey, 2003: 164). Because these conditions often are not present, decision-makers must use judgment and intuition, and undertake in bargaining and political maneuvering in their decision-making process. According to Rainey, James Thompson asserted that the level of agreement amongst decision-makers on goals and the amount of technical knowledge amongst decision-makers on how to implement solutions or tasks determined whether or not a decision-making process could be rational. When the level of agreement and amount of knowledge are high, rational processes are more likely to be followed (2003:164).
3. The “*Incremental Decision-Making*” approach. Relying upon Charles Lindblom’s (1950) “The Science of Muddling Through,” Rainey states that the responsiveness of decision-makers to “the requirement for political consensus and compromise” necessarily leads to unclear goals that result in the restricting of “the size of the changes [decision-makers] propose” (Rainey, 2003: 165-166). In other words, instead of choosing an alternative that a rational decision-making process would predict, decision-makers choose to make less controversial, intermediary decisions to ensure some degree of success of achieving vague goals presented.
4. “The *Garbage Can Decision-Making*” approach. This idea “comes from the observation that decisions are made in organizations when particular decision-making opportunities or requirements arise” (Rainey, 2003: 167-168). In this model, “it is often unclear who has the authority to decide what and for whom” (Rainey, 2003: 168). It is the antithesis to the rational decision-making model; solutions can be developed before problems are determined to exist (*Id.*; See also Kingdon, 2003, pp. 84-86). In other words, instead of following the aforementioned “conveyor belt,” decision-makers may be waiting for an opportunity to advocate actions already planned. Once attention is brought to a problem that is related to their kept-on-the shelf action, decision-makers then propose it at this time (Kingdon’s (2003) term for this opportunity is a “policy window” (p. 166)).

In the domain of environmental management or policy, it is probably safe to say that most developers of eco-informatics tools or information *hope* that their work will be utilized in some form of rational decision-making processes or that at the very least, their tools and information are used to help inform incremental decision-making processes. For example, Tonn, et al. (2000: 165-166) provide a framework to guide environmental decision-making in which goals and values are agreed upon, planning is pursued, and then decisions are developed and implemented. Elements that comprise an environmental decision include the goals and values of different parties involved, the conflicting perceptions of the problem, and available knowledge (e.g., eco-informatics-based information). Within this broad context, issues are diagnosed, hopefully with a combination of general foresight, monitoring the environmental status quo, and evaluating decisions already made. As issues are diagnosed, appropriate “decision-making modes” are assigned. These modes include, amongst others, “emergency action,” “routine procedures” and “collaborative learning,” each representing a different decision-making attitude within the framework (Tonn et al.:170-171). Once the mode is assigned, the decision is developed through a series of rational steps: Issue familiarization, criteria setting, option construction, option assessment and reaching the decision. Ecoinformatics come into play in various parts of this framework, whether in issue diagnosis, monitoring present situations, or in option construction (see Tonn et al: 169, 168, and 174). Although “ecoinformatics” is not a term used by Tonn and colleagues, the general supporting data and models they refer to would be considered eco-informatics components.)

Approaches to help actors make decisions between alternatives

There is a vast body of literature in fields such as operations research, decision or management science, ecological economics and others that describe various approaches to help

single or group decision-makers analyze their situation and weigh alternative choices. Many of these approaches are designed to be used in rational decision-making settings (described earlier), but they might also be applied in some “incremental” eco-informatics decision-making settings.

Optimization approaches (e.g., linear or nonlinear programming, discrete optimization) can be applied in decision settings where there is a single criterion to base a decision on (such as cost) (Nemhauser, et al. 1989). Multiple criteria optimization techniques also exist when there are a finite number of criteria but the number alternatives to choose from is infinite (Steuer, 1986). But perhaps more common are decision situations where there are a number of criteria and alternatives to consider. These types of decision-making situations where the goal is to identify a single most preferred alternative is referred to as multi-attribute decision-making problems. Simple approaches not requiring computing have been developed, such as “pros and cons analysis”, maximin and maximax methods, conjunctive and disjunctive methods and lexicographic methods (Baker et al. 2001; UK DTRL, 2001), but are best suited for problems with a single decision-maker and few alternatives. These tend not to be characteristic of environmental decision-making settings (Linkov et al., 2004).

At the same time, more sophisticated and computer-based methods for decision-analysis have emerged, including approaches based on Multi-Attribute Utility Theory (MAUT; e.g., Keeney and Raiffa, 1976; Edwards, 1977; Edwards and Barron, 1994; Mészáros and Rapcsák, 1996; Saaty, 1980; Triantaphyllou, 2000; and Figueira et al, 2004); Outranking (Roy, 1968; Brans and Vincke, 1985; Brans et al. 1986; UK DTRL, 2001; Figueira, 2004) and Cost-Benefit analysis (UK DTLR, 2001). Interested readers are encouraged to read the accompanying paper by Fülöp (2005 [[Judy - hyperlink here to Janos' longer paper if it is placed on the workshop website](#)]) that describes these approaches in more detail. These, along with many other computer-based analytic tools and approaches (such as GIS-based models or quantitative analysis based on empirical data) provide examples of the intersection of eco-informatics and decision-making, perhaps more often in the context of one analyst or one organization.

However, other settings involve groups of people or organizations trying to make a decision related to the environment or environmental management and policy, and in these settings, there are relevant multi-attribute decision-making approaches. For example, Bose et al. (1997) provides a review of early MAUT methods applied to group settings. One such approach, the Analytic Hierarchy Process (Saaty, 1980) has been applied to group settings (see Dyer and Forman, 1992, Lei et al. 2002 and an alternative approach was proposed by Csáki et al., 1995). These types of situations – where preferences of various groups or stakeholders need to be considered – are a critical research area in the eco-informatics and decision-making domain.

Another important point related to the various decision-making tools and approaches cited above as well as others falling in the domain of eco-informatics is that often variables used in computer-based models (such as multi-attribute decision models) are set to subjective values. These models may contain uncertainties, either because subjective scoring or are based upon some data or model output that contain some level of uncertainty. It is therefore an important question how the final ranking of alternatives are sensitive to the changes of input parameters contained within the decision model and how uncertainties are communicated to the user through analytic tools. Examples of research in this area include Triantaphyllou and Sanchez (1997), Mészáros and Rapcsák (1996) and Ekárt and Németh (2005).

Two Important Issues: (1) Politics and (2) Complexity

Up until now, the discussion has focused primarily on decision-making situations that are more rational or perhaps incremental in nature. However, some scholars lament the fact that various eco-informatics-based tools, computer-based models and information are utilized as “weapons in political and policy warfare,” while others accept this supporting role, focusing more on how they are used to persuade decision-makers of alternative interpretations of these

information (King and Kraemer, 1993; Mazurek, 1996; Hendriks, et al., 2000). Back in 1993, King and Kraemer noted that computer-based models were specifically constructed to provide results that supported proposed policies of decision makers. It is likely that in the fifteen or more years since this use (or misuse?) of eco-informatics tools and information has only increased as eco-informatics tools become easier to use by policy analysts.

Others worry about the complexity of eco-informatics-based computer models and decision makers' abilities to understand them. One issue is that in environmental situations issues are complex and there are may be uncertainties, but in political and policy situations many decisions are placed in a "yes or no" context. Another issue has to do with the complexities of eco-informatics tools and output and often the need to communicate these results to policy-makers, analysts (and citizens) who may not have the relevant educational background to understand them. For example, Briassoulis (2000) states that, although models (in her case, computer-based land-use models) should be developed with a wide variety of users in mind (e.g. education level), models are instead being solely developed for an "elite of educated users" (see section 5.1.4). Given that decision makers may not fall into these elite, Briassoulis argues that it is therefore the elite's responsibility to educate, objectively, the decision-makers on the assumptions and conditions relied upon in such decision support models (*Id.*). Still, she is optimistic that such models, if developed properly, can positively support decisions in the process of being made (see section 5.2).

In many (perhaps most) contexts, it is probably the case that developers of eco-informatics tools develop these methods without too much concern for the context in which such tools will be applied to decision making. Developers may focus more on getting the tool right (scientifically) and concentrate less on how the tool might be used or abused in particular decision-making settings. A simple example of this is in evolution of statistical software, where it becomes easier and easier for a user to run a method with little or no understanding of the assumptions or processing being done "under the hood".

Conclusion

To summarize, literature on public sector decision making¹ emphasizes that it is not a benign pursuit. There is no real consensus on how decisions are made. Theories range from mechanical approaches (Rational Decision-Making) to those that assume no constants at all (Garbage Can). Within environmental decision-making, the quest for a more efficient means of developing policy is still ongoing. The role of supporting, scientific information (e.g., eco-informatics-based information) in environmental decision making is also being debated. This is one reason why this particular workshop on eco-informatics and decision-making is important.

The "ideal" model of eco-informatics decision-making is that it follows a rational process, and these decisions are informed by "facts" that are generated through good science coupled with eco-informatics tools, procedures and analyses to produce these facts. The reality is that decision-making (at least in the public sector, but probably also in other sectors as well) is often infused with processes that do not follow a "rational" approach, and are often infused with uncertainty in the data or analysis provided and are under pressure for alternative political interests. Given the complexities inherent in public sector decision-making processes, none of these statements should be surprising. However, a research program centering on eco-informatics and decision-making should be cognizant of these environments and perhaps help to alleviate – or at least expose – some of the negative consequences of these kinds of "non-rational" processes.

¹ We should note that in preparation of this paper we also did research on decision-making processes in non-profit organizations knowing that they, too, are extremely active in eco-informatics-based decision-making. Much of what we described earlier is probably relevant in both private and non-profit settings as well and Rainey (2003) makes this point.

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