1.6. Decision Science Methods

Recent research and practical work in the decision sciences has focused on ways to help structure and improve the process by which people make environmental, risk, and resource management decisions (e.g., Arvai and Gregory 2003, Failing et al. 2004, Trousdale and Gregory 2004, Gregory et al. 2006, Arvai et al. 2007). Many of these efforts are informed by research in psychology and economics, which suggests that for many unfamiliar and multiattribute decision contexts, people's preferences and preference orders are not well formed. Instead, people's preferences are constructed, rather than revealed, based on how they process certain cues that are apparent or implicit (e.g., given their own conceptualization of a problem) during the elicitation process (Payne et al. 1992, Slovic 1995, Payne et al. 1999). As a result, decision structuring processes focus on helping people to decompose complex problems; these approaches involve working with stakeholders, experts, and decision makers to clarify several steps in the decision making process, often iteratively (Arvai et al. 2001).

There are five basic steps that must be followed in a structured, multiattribute decision making process; these are (1) eliciting and structuring the objectives that will guide the evaluation of alternatives, (2) identifying attributes for each objective and operationalizing these by acquiring data that will characterize the effectiveness of the alternatives in terms of how well they meet stated objectives, (3) establishing a utility function that incorporates all of the objectives, and their related attributes, that will guide the decision, (4) eliciting weights for each attribute in the utility function, and (5) aggregating weights and utility functions in the evaluation of the contending alternatives. The overall goal of this process is to identify the optimal alternative in a set while also recognizing that important objectives will conflict; i.e., it will not be possible to optimize across all of the objectives (Keeney 1992, Keeney and Raiffa 1993).

One of the keys to these multiattribute decisions is the manner in which a decision maker addresses important value tradeoffs. Decision makers and analysts must ask, how much achievement with respect to one objective (e.g., minimizing costs) is one willing to give up in order to obtain a higher level of achievement with respect to another objective (e.g., improving health)? Answering these kinds of questions for simple decisions may involve the informal weighing of tradeoffs in the mind or, as the complexity of the decision context increases, a more formal and explicit characterization of a value structure applied to all of the contending alternatives. Moreover, there are no 'right' or 'wrong' answers to these kinds of questions; tradeoffs, by necessity, require subjective judgment on the part of those individuals or groups that are charged with addressing a given decision problem (Keeney and Raiffa 1993). Rather than focusing on finding the 'right' answer, the goal of a structured decision approach is to help people establish their values and preferences about alternatives via a formalized, thoughtful, and defensible process (Gregory et al. 2001).

One of the questions before this committee was to determine how lessons and approaches from multiattribute decision making could be applied to the issue of valuing the protection of ecological systems and services. It is important to note that the committee's work with respect to answering this question did not include providing guidance about *how* EPA should make decisions. Such advice fell outside the charge of this committee.

In considering only the question of valuation, the committee believed that methods informed by multiattribute decision making could be useful to EPA. In the absence of actually *selecting* a preferred course of action (i.e., decision making), both the quantitative score (via the quantitative assessment of utility functions) and the rank ordering of alternative environmental states could be used by EPA to determine which is most "valuable". Moreover, multiattribute methods could be applied in three comparative valuation contexts.

First, these methods could be used to help EPA evaluate alternative environmental states from a *prospective* standpoint by determining, for example, which in a range of environmental, risk, or resource management options is most likely to lead to a preferred suite of environmental outcomes. In other words, applying multiattribute methods in this way would help EPA to determine which in a set of alternative environmental states is the most valuable (i.e., *does Management Option A lead to better environmental outcomes—i.e., outcomes that are more valuable to people—than Option B?*). Second, the value of ecological systems and services may be determined *retrospectively* by comparing attributes associated with ecosystem health or the provision of ecological services that have been realized today with those that were realized at some point in the past (i.e., *is the system being evaluated "better off"—or more valuable—today, at Time 2, than it was in the past, at Time 1?*). Third, value may be determined in a *spatial* comparison by evaluating the attributes associated with ecosystem health or the provision of ecological services in an area of interest relative to those that have been realized elsewhere (i.e., *is System A more valuable than System B?*).

The application of a valuation method that is informed by structured decision making follows the same five steps outlined above. Steps 1 and 2 are used to identify and then operationalize the suite of attributes that will characterize the ecological systems and services that are of interest. For example, people may determine the value of a estuary based on multiple, ecologically-based attributes such as the degree to which it provides nutrient exchange, the re-supply of dissolved oxygen to near-shore habitat, or nursery habitat for anadromous fish species. Similarly, the value of the estuary will also be affected by a wide range of attributes that reflect economic or social interests, such as the degree to which it provides access to commercially important species, opportunities for recreation, and lanes for shipping traffic.

Step 3 involves developing a utility function that integrates the suite of attributes (e.g., for the hypothetical estuary outlined above) and is ultimately used to estimate value associated with an environmental system. While these functions may take many forms—e.g., they may be additive, logarithmic, exponential, etc.; for a complete description, see Keeney and Raiffa (1993)—they all involve the application of a scaling or weighting variable applied to each attribute. It is these weights that help an analyst, or analysts, to address tradeoffs, essentially asking which attributes are more or less important when estimating the overall value of a system.

An analyst next elicits the weights that will be used to determine the relative importance of each attribute in the valuation exercise. Weights can be elicited from both individuals and groups; in either case it is important that weights be elicited *after* the different attributes in the utility function have been operationalized. In other words, weights should only be elicited after an analyst has obtained data that characterizes each attribute present in the utility function for the alternative systems being considered (i.e., for alternative plans in a *prospective* context, at all of the sites being considered in a *spatial* comparison, and for all of the times being considered in a *retrospective* analysis).

The rationale for waiting until the attributes have been operationalized is straightforward: It makes little sense to prioritize attributes until one has a sense of the magnitude of the tradeoffs that will need to be made. In many cases, for example, people will state that environmental protection is "worth it" at any price. But if pressed, they will agree that when eliminating 99% of the contaminants at a hypothetical site costs millions and eliminating the *remaining* 1% costs additional billions, the marginal improvements may, in many instances, not be worth the additional cost. Therefore, assigning weights after the attributes of value for the system of interest have been operationalized allows both the analysts and those who will be providing weights to gain a better understanding of what may (or may not) be gained by placing a higher weight on one attribute over another (Keeney 1992, Hammond et al. 1999). Once weights have been elicited, the final step in a valuation method that is informed by structured decision making is to aggregate the weights and utility functions in order to 'score' the systems that are being compared.

The different ways that weights may be elicited range from the relatively simple to the more complex. For illustrative purposes, four methods are described briefly here. For all of these methods, respondents are often allowed to adjust their weights across the various attributes as they become more familiar with both the elicitation procedure and the tradeoffs implied by their weights.

First, respondents may simply be asked to assign 100 *importance points* across the various attributes that will be aggregated to establish the value of a system. However, respondents often have difficulty with such tasks because they fail to adequately address the relative weight placed on each attribute. An alternative is to elicit *ratio weights.* Here, respondents are first asked to rank the various attributes from most to least important; then, starting with the least important attribute, respondents are asked to assign a specific low value such as 10. Each of the remaining attributes in the ascending set is then judged against this baseline value as multipliers of 10; e.g., the next most important attribute may be only 10% (or 1.1 times) more important while the highest ranking attribute may be 1000% (or 10 times) more important (Borcherding et al. 1991).

In *swing weighting* respondents are presented with only the best and the worst consequences associated with each attribute and are told to assume that they are faced with a situation where the system they are evaluating possesses all of the worst consequences. They are then asked to identify which of the attributes they would most want to swing from the worst to the best consequence in order to make the largest improvement to the system. Respondents repeat this procedure for all of the attributes in the set. Once all of the attributes have been ordered in this way, respondents are typically asked to assign 100 points to highest ranking attribute with the others assigned a percentage of this weight. A weight of zero is assigned to swings on attributes from worst to best that are judged to be irrelevant (Clemen 1996, Baron 2000).

A variation on swing weighting is to ask respondents to assign weights by *pricing out* the various attributes (Borcherding et al. 1991, Clemen 1996). As with swing weighting, only the best and worst consequences associated with all of the attributes are shown. Then, respondents are asked to indicate how much they think society ought to pay in order to exchange the worst consequence for the best one. For attributes where the consequences are expressed in monetized unites, the payment amounts associated with exchanging the worst consequence for the best are implied and, as a result, respondents are typically not asked to evaluate them. Elicited prices may then be converted to normalized weights prior to using them in a utility function.

In some cases—particularly when one attribute of value involves monetized costs or benefits—it may also be possible for EPA to apply a modified decision structuring approach, one that does not require the computation of a utility function. An analyst would still be required to identify all of the relevant attributes of value for a system and operationalize them. But rather than weighting these attributes in a utility function, they would instead be displayed in a consequence table that compares the consequences associated with each attribute across the systems of interest (i.e., in a prospective, retrospective, or spatial context). An analyst would then ask respondents to swap non-monetized attributes with either monetized benefits or costs.

For example, one could ask which of two water management programs more valuable: A hypothetical EPA program that restricts activities in a watershed by 25% and results in net benefits to users of $10 million or a different state-run program that restricts activities by 22% and results in net benefits of $8 million. Here an analyst would focus respondents' attention on the state run program and ask them what level of additional monetary benefits would justify an increase in restrictions from 22% to 25%. An increase in judged benefits of less than $2 million would imply that the benefits of the state-run program was more valuable to respondents than the EPA program and vice versa. This approach to evaluating tradeoffs, termed *even swaps* (Hammond et al. 1998, Hammond et al. 1999), can—and has been—used when comparing systems with 2 or more attributes.

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