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TRADE OFF ANALYSIS IN ENVIRONMENTAL DECISIONMAKING: AN ALTERNATIVE TO WEIGHTED DECISION MODELS

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ABSTRACT

This paper reviews the weighting and aggregation of project impacts in weighted decision models commonly employed for environmental decisionmaking, and proposes an alternative method, the systematic analysis of project impacts, for certain decision problems. Advantages of weighted decision models include the explicit quantification of decision-maker values and the usefulness of systems analysis techniques for optimizing decisions. Disadvantages include the assumption of unanymity of values among affected publics and unresponsiveness to the needs of many participants in the decisionmaking process. For controversial decision problems with substantial implications for different social groups, explicit analysis of trade offs among impact areas or project goals is advanced as a method superior to the quantitative weighting and aggregation of impacts.

Introduction

In response to the National Environmental Policy Act of 1969 (NEPA) and similar state environmental legislation, numerous "systematic, interdisciplinary" methods have been proposed to incorporate broad environmental and social concerns within public decisionmaking. A convenient classification of these methods is 1) ad hoc, 2) overlays, 3) checklists, 4) matrices, and 5) networks [1].

Of these five, impact matrices are perhaps the most promising and widely-employed for meeting the mandate of environmental

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legislation while staying within time and budget constraints encountered in applied settings [2]. To use impact matrices, analysts systematically establish cause-and-effect links between separable project components and a predetermined list of impact areas. The magnitude of impact in each component/impact area cell is then estimated and usually is subjectively rated on a scale such as +, 0, - or +5 to -5.

Following the rating of impact magnitude, the impact areas may be subjectively weighted for importance. This allows the impact matrix, in effect, to be used as a weighted decision model: a single summary score of project desirability can be calculated by adding the products of the magnitude and importance scores, and the summary scores of alternative projects can be compared. The importance weights for impact areas may be solicited from decisionmakers by techniques such as paired or successive comparison of impact areas.

It is not universally agreed that impact matrices should be used as weighted decision models by weighting and aggregating impact areas. L. B. Leopold, responsible for popularizing the environmental impact matrix, proposed that impact areas be subjectively weighted only to highlight the most significant project impacts [3]. More generally, the desirable degree of impact aggregation is a "hotly debated" generic issue encountered not only with impact matrices, but with most systematic environmental evaluation methods as well [1].

This paper will explore the issue of impact aggregation in environmental decisionmaking and advance the case for use of a different method, the explicit analysis of trade offs among impact areas or project goals, as superior for certain decision problems.

The Weighting And Aggregation of Impacts

PERVASIVENESS IN ENVIRONMENTAL EVALUATION

Cost-benefit analysis (CBA), often proposed by economics-oriented analysts as the ideal environmental decisionmaking method, is probably the most well understood example of impact aggregation, and demonstrates perhaps most clearly the problems attendant in "adding apples and oranges." The implicit weighting rule in CBA is that each discounted dollar of cost or benefit is equally important, leading to a "one dollar/one vote" decisionmaking calculus. The use of a single aggregate index, such as net benefit or benefit/cost ratio, to summarize project desirability has been criticized on numerous theoretical and practical grounds [4]. Impacts that are either non-monetizable, low probability/high risk, or uncertain are not easily incorporated; willingness-to-pay as a measure of project benefits is a questionable procedure because of market imperfections and income constraints (suggesting that willingness-to-accept compensation may be the more appropriate measure of benefits [5]); future generations appear to be given short shrift when costs and benefits are discounted to present values; and as a direct result of aggregating impacts across affected groups, the distribution of costs and benefits is ignored.

The general inability of CBA to incorporate values other than economic efficiency was at least partially responsible for NEPA's mandate that federal agencies use evaluation methods insuring the "integrated use of the natural and social sciences and environmental design arts" in making decisions. Aside from impact matrix approaches described in the introduction to this paper, two other examples of commonly-employed environmental decisionmaking tools with an interdisciplinary emphasis are goal programming and map overlays, both of which squarely encounter the problem of impact aggregation.

Goal programming, also known as multiple objective programming, is advocated as a method for resolving conflicts between economic efficiency and environmental enhancement in water resources planning. (A variant of this method, the goals-achievement matrix, is advanced by Hill as a method for evaluating alternative plans [6].) In goal programming, competing project goals are subjectively weighted for importance and a multiple goal objective function, representing project desirability, is optimized. Although superior to CBA because it incorporates explicitly environmental values and the distribution of impacts, goal programming has been criticized by authors such as Butcher [7], who believes that faith in the ability of methods such as goal programming to arrive at a single quantitative index of project merit is "an idealistic fantasy." Butcher recommends the development of "less elegant, but more realistic" decisionmaking tools for water resources planning.

The map overlay technique involves the overlaying of a series of maps depicting different land characteristics to produce a land capability analysis. Each transparency contains calibrated coloration representing the suitability of a parcel of land for a single characteristic, such as slope or soils. When the transparencies are overlain, the darkest areas represent the least (or most) suitable sites for the particular activity under consideration. The implicit weighting rule used in map overlays is that all land characteristics are equally important, an assumption that may be valid for some land capability analyses but clearly not for all.

McHarg, largely responsible for disseminating the map overlay method, recognizes the inherent weighting problems, but perceives "no possibility" of quantitatively weighting the various land characteristics: "It is quite impossible to compare a unit of wildlife value with a unit of land value, or to compare a unit of recreation value with one of hurricane value . . . exact resolution of these problems seems unrealizable [8]." Nevertheless, when land characteristics are clearly of unequal importance, attempts have been made to subjectively weight the land characteristics, and then, typically, to use the computer to calculate and map summary scores of suitability [9].

Advantages and Disadvantages of Impact Aggregation

ADVANTAGES

The advantages of impact aggregation in weighted decision models will be only briefly summarized here. The primary advantage of impact weighting is that the values of decisionmakers are explicitly stated and quantified. Impact weighting forces the decisionmakers to finalize their thinking and concisely state their assumptions and evaluations of the relative importance of impact areas. Once decisionmakers so quantify their values, the choice of a "best" alternative project appears unambiguous. Also, because both impact magnitude and impact importance are quantified on similar scales, well-developed systems analysis methods can be used to optimize decisions. The increasingly important role of systems thinking in engineering, management, and economics has perhaps inevitably led to the development of environmental decisionmaking tools which are direct descendents of systems theory and technique.

DISADVANTAGES

Weighted decision models can be criticized on at least two grounds. First, are the importance weights meaningful? At best, they can accurately reflect the values of the decisionmaker, and at worst, they reflect the values of the technical expert. In either case, it is assumed that a unanymity of values exists among the multiple publics affected by a decision and that one set of average value weights can capture this preference. Friedmann, among others, questions these assumptions, noting that:

> . . . values are to a large extent formed by the location of the observer in the social matrix. The resulting multiplicity of societal perspectives cannot by force of logic be integrated into a single normative scheme or, as planners like to put it, a hierarchy of values [10].

Of course, the values of different social groups will have to be compromised eventually to reach any decision, but democracies traditionally rely on the political process (with all attendant irrationalities) to resolve conflicts in values. Thus, the popularity of weighted decision models in one sense can be interpreted as a shift from democratic to technocratic decisionmaking style as the decision problems themselves take on an increasingly technical nature.

A second, related, disadvantage of weighted decision models is that they are often unresponsive to the needs of individuals and social groups wishing to participate in the decisionmaking process. Analysts may devote greater energy to developing sophisticated mathematical decisionmaking models than to providing information to and soliciting reactions from the publics affected by a decision, and the technical procedures used for evaluation begin to rival the results of the evaluation in terms of importance. Specifically, important information on trade offs among impact areas or project goals is often lacking in evaluations using weighted decision models. Though this information would appear to be captured in the table of decisionmaker importance weights, the average weights are of little use to those whose values lie on the extremes of the distribution.

Explicit Trade Off Analysis: An Alternative Approach

Perhaps impact aggregation is a "hotly debated" issue because the procedure is considered in the abstract, without reference to a particular decision context. Lee, in a critique of large scale planning models, recommends that analysts start with a particular problem that needs solving, rather than with a particular methodology that needs applying [11]. Lee advises analysts to "work backward" from the problem, matching specific methods with specific purposes.

Lee's advice is applicable to project evaluation as well as to planning models. Consider two idealized types of decision problems involving choice among alternative projects. The first type is high in technical content, will be resolved based on the accumulated knowledge of technical experts, and requires little input from affected publics; an example is whether a municipality should use trickling filters or activated sludge as a secondary sewage treatment process. The second type of decision problem, although not without significant technical aspects, will be resolved by the political process and requires much informed public input because the decision will differentially affect different social groups in major ways; an example is the design and siting of a major dam.

Weighted decision models seem appropriate for the first type of decision problem, but inappropriate for the second. In the second type of problem, basic disagreements in values among affected publics are inevitable, and the goal of the analyst is to provide accurate and meaningful information for use in the political arena, the proper forum for resolving significant value conflicts.

In controversial decision problems with substantial social implications, then, an alternative to weighted decision models is to provide usable information on trade offs among impact areas or project goals to participants in the decisionmaking process. Miller and Byers support this approach, noting that "if the trade off information is provided to all interested public agencies, private groups, or individuals, the political process can be used to select the socially optimum project design [12]." The greater the technical complexity of such a controversial decision problem, the greater the obligation of the analyst to translate highly technical information to the type of information on impacts that can facilitate the participation of affected publics in the decisionmaking process.

Table 1 presents one possible format for the display of trade off information in a decision problem with substantial differential social implications. The example is taken from an evaluation of land-based alternatives for the disposal of large quantities of sewage sludge generated in a City of Los Angeles treatment plant [13]. Equipped with such comprehensive information on the impacts of alternative projects, informed participants in the decisionmaking process can better weigh the merits of each alternative to arrive at an acceptable decision.

Table 1. Trade Off Analysis for Three Land Based Sewage Sludge Disposal Alternatives

Agricultural alternative	*Evaporation ponds alternative*	*Landfilling alternative*
In order to implement this alternative, public and decision-makers would prefer to see:	*In order to implement this alternative, public and decision-makers would prefer to see:*	*In order to implement this alternative, public and decision-makers would prefer to see:*
• improved soils on 10,300 acres of Antelope Valley land currently useless for agriculture; • multiple use of this site to recycle wastes and grow crops; • retention of 16,800 acres (including buffer zones) in open space and agricultural use; • the creation of more jobs than the remaining alternatives and production of $690,100 in crops; • strengthening of the Antelope Valley agricultural sector; and • recycling of 55.2 million gallons per day of secondary effluent.	• implementation of the least-cost alternative, with costs equivalent to $0.82/capita/year; and • implementation of the least energy intensive alternative, with requirements equivalent to 0.69 gallons gasoline/capita/year.	• implementation of an intermediate-cost alternative, with costs equivalent to $1.26/capita/year; and • the creation of an intermediate number of new jobs (at least 33).

Table 1. (Cont.)

Agricultural alternative	*Evaporation ponds alternative*	*Landfilling alternative*
At the same time, public and decision-makers must be willing to accept: • high costs, equivalent to $1.93/capita/year, over twice those of the evaporation ponds alternative; • high energy requirements, equivalent to 7.8 gallons gasoline/capita/year, over 11 times those of the evaporation ponds alternative; • high air pollution emissions, potentially nine times as damaging to health as emissions from the evaporation ponds alternative; • possible contamination of the Antelope Valley groundwater basin; • some increase in traffic; • noise, dust, odor, and visual impacts; and • potential public health impacts.	*At the same time, public and decision-makers must be willing to accept:* • a relatively minor increase in air pollution emissions; • removal of soils and native vegetation on 656 acres of Antelope Valley land; • possible contamination of the Antelope Valley groundwater basin; • the creation of the least jobs among the alternatives; • increased traffic (30 truck round-trips daily); • noise, dust, odor, and visual impacts; • potential public health impacts; and • foregoing the opportunity to recycle sludge and effluent.	*At the same time, public and decision-makers must be willing to accept:* • high energy requirements, equivalent to 7.5 gallons gasoline/capita/year, over ten times those of the evaporation ponds alternative; • an intermediate increase in air pollution emissions; • possible contamination of the Santa Monica groundwater basin; • discharges of heated effluent and evaporator condensate to the ocean; • potential effects on marine ecosystems of these discharges; • increased traffic (44-56 truck round-trips daily); • noise, dust, odor, and visual impacts; • potential problems with the future use of Mission Canyon as a park; • potential public health impacts; and • foregoing the opportunity to recycle sludge and effluent.

Conclusion

The use of weighted decision models in environmental decisionmaking is subject to debate at least partially because analysts fail more carefully to match specific evaluation methods with specific decision problems. For highly technical decision problems with few social implications, the advantages of weighted decision models—explicit quantification of values and easy interface with systems analysis techniques—argue strongly for the use of this evaluation method. On the other hand, for decision problems with substantial differential social implications, explicit presentation of trade off information, as in Table 1, allows each participant in the decisionmaking process to arrive at informed conclusions as to project merit using each participant's own value structure; the quantification of decisionmaker value weights in these cases would discourage meaningful participation of affected publics in decisionmaking.

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