Decision Making in Hazard and Resource Management*

by

Howard Kunreuther and Paul Slovic

Problems of decision making have been a focal point of research in the social and behavioral sciences over the past twenty-five years. These topics were introduced to geographers by Gilbert White, whose work subsequently sensitized economists, psychologists and sociologists to problems in hazard and resource management that were amenable to formal and behavioral analysis.

White has emphasized the importance of understanding how individuals and groups make decisions about alternative programs for coping with hazards. Specifically, he has sought to demonstrate how empirical study of decision processes can aid the development and selection of public policy alternatives. His concern with linking descriptive models of choice to prescriptions for policy is summarized in the preface of his book, Strategies of American Water Management:

> The theme of this volume is that by examining how people make their choices in managing water from place to place and time to time we can deepen our understanding of the process of water management

*We would like to acknowledge the helpful discussion and comments on an earlier draft of this paper by Mike Eleey, Ed Haefele, John Jackson, Paul Kleindorfer, Allen Kneese, Harold Marshall, Jerry Milliman, Clifford Russell, William Wallace and William White. Special thanks should go to Ian Burton and Robert Kates for their guidance during the preparation of this chapter. Support for this chapter comes, in part, from the Technology Assessment and Risk Analysis Program of the National Science Foundation under Grant PRA79-11934 to Clark University under subcontract to Perceptronics, Inc., and the Bundes Ministerium für Forschung und Technologie, FRG Contract No. 321175911 RGB 8001. Any opinions, findings and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of these sponsors.

> and thereby aid in finding more suitable ends and means of manipulating the natural water system. (p. viii).

The present paper highlights this theme by selectively surveying research on decision making and describing the implications of these results for hazard and resource policy. We will indicate what has been learned from this research, its influence on public policy, and the promising directions for future study. Figure 1 provides a schematic model which will guide our approach to decision making. Decision makers collect and process information based on their perceptions of the environment and the available options. Their final choice reflects numerous constraints imposed by their limited ability to collect and process information. As we shall see below, White's empirical analyses have deepened our understanding of the limitations of individual and societal decision making. His work reflects a concern with the question: "What should we do differently now that we have learned more about human behavior?" Underlying this concern is a philosophy that policies and programs should be based on the realities of the environment and human behavior rather than on unproven theoretical models. We share this perspective.

Insert Figure 1 about here

White has been concerned with decisions made by both individual managers and the public. We will survey the research in these two broad areas, concentrating on problems of hazard and resource management. The concluding section of the paper provides guidelines for future policy-related research.

I. Individual Decision Making

What protective actions do individuals undertake to deal with hazards which they face? What actions should they undertake? Some hazards, such as floods, occur rarely but may produce severe damage when they do occur. Other hazards, such as hail, may occur more frequently but result in relatively little damage. Recognizing that each specific hazard requires a special set of protective adjustments, White made an important contribution to the literature of resource management by developing a framework for structuring the analysis of adjustment decisions. In particular, he distinguished between the theoretical and practical ranges of choice:

> The theoretical range of choice open to any resource manager is set by the physical environment at a given stage of technology. The practical range of choice is set by the culture and institutions which permit, prohibit, or discourage a given choice (White, 1961, p. 29).

Consider the options open to homeowners residing in the flood plain. Individuals would have an opportunity to reduce the magnitude of flood losses by elevating their structures or adopting flood-proofing measures. They could deal with the financial consequences of disasters by purchasing insurance, relying on federal aid or bearing the loss entirely themselves. The practical range of choice open to any homeowner may be smaller than the above set either because of a blocked option or because of limited knowledge by the resident. For example, prior to 1953, the Federal government did not have a systematic program of disaster relief. Flood insurance was not available to homeowners until after 1968 when the National Flood Insurance Program was initiated. Techniques for reducing flood damage to residential structures in the flood plain have been effective in the flood plain in recent years, but many residents are still unaware of these possibilities.

Table 1 depicts examples of the practical range of choice considered by a homeowner on the flood plain (Ms. Waterman) and her estimated consequences to personal wealth under three different states of nature; no flood, mild flooding and severe flooding--with estimated probabilities of .90, .09, and .01, respectively.

Insert Table 1 about here

If there was no flooding, she would be better off not purchasing insurance or elevating her house. Minor or severe flooding justifies both of these options in comparison with the other two. Ms. Waterman would also conclude that it would never be optimal for her to bear the loss herself if federal relief was easily available. If, on the other hand, there was considerable red tape in obtaining disaster relief or Ms. Waterman was opposed to handouts from the government, then she might decide to bear the loss.

The analysis of Ms. Waterman's problem can be structured in a number of different ways. Decision analysis is the most sophisticated of the methods as it forces the decision maker to systematically evaluate each alternative. Behavioral approaches, which are of more recent vintage, incorporate the limitations of individuals in processing information. We will survey these two broad approaches in the context of Ms. Waterman's problem.

Decision Analysis

Structuring the probem to determine the relevent adjustments, events, probabilities and consequences (as in Table 1) is a major and crucial first step, still as much of an art as a science. We shall assume the above structure (Table 1) and proceed to the calculations involved in comparing the various decision options. The methodology for determining an optimal solution "requires that preferences for consequences be numerically scaled in terms of utility values and that judgments about uncertainties be numerically scaled in terms of probabilities" (Raiffa, 1968, p. x). A principal argument for using such an approach is that it is based upon a reasonable set of assumptions regarding behavior and choice. These assumptions imply that the consistent decision maker behaves as if he or she assigns probabilities to different states of nature (e.g., chances of a severe flood), assigns numerical utilities or disutilities to the possible results of each course of action (e.g., the disutility of a severe flood with no insurance protection) and then chooses the action yielding the highest expected utility. In other words, the theory provides a rational means for making decisions by prescribing the course of action that conforms most fully to the decision maker's own goals, expectations, and values.

An integral part of the decision analysis approach is constructing a utility curve which reflects the value of different outcomes to the decision maker. In the case of Ms. Waterman, assume that she is averse to risk so that a gain of $100 is worth proportionately less to her than a loss of $100. One way of representing this attitude toward money is to convert dollars into utilities by presenting Ms. Waterman with a specific lottery or gamble and asking her to specify a dollar value A which reflects an indifference to receiving this amount with certainty or playing the lottery. For example, since she is risk averse, she might specify A to be $40 when presented with a lottery consisting of a coin flip to determine whether she has won $100 (heads) or received nothing (tails). By undertaking a series of such comparisons between lotteries and certainty equivalents, we can draw Ms. Waterman's utility curve, which enables us to evaluate different alternatives such as the ones in Table 1. Such a curve has been drawn in Figure 2, where we have arbitrarily specified the relevant end points of \$0 to have a utility of 0 and \$20,000 to have a utility of -100.[1]

Insert Figure 2 about here

We are now ready to specify an optimal choice for Ms. Waterman. The analysis is graphically depicted in Figure 3 by a decision tree with small squares representing the options and circles representing the states of nature. At the end of each path, there is a disutility associated with a particular decision and a specific event. For example, the expected utility associated with bearing the loss herself would be -2.8. The optimal decision for this example would be to purchase insurance, since the expected utility is -.10.

White (1966) has pointed out that the resource manager may often want to choose a combination of adjustments to deal with a particular problem. Decision analysis also enables one to undertake such alternatives. In the previous example, if Ms. Waterman was able to obtain reduced insurance premiums for elevating her house (because it was now less prone to flooding than before), she might have considered adopting both of these options. The decision tree would then have been expanded to include a fifth option, "elevate house and purchase flood insurance," and the expected utility computed in the same manner as outlined above.

In summary, there are three interacting factors which jointly determine the optimal choice using the decision analysis approach: (1) the shape of the utility curve, (2) the estimate of probabilities of different states of nature, and (3) the estimates of the consequences associated with each alternative given a specific state of nature. In the above example, if Ms. Waterman has assumed that minor or severe flooding in her area would produce little damage to her home, then she might not have found insurance attractive. Similarly, if she had felt that any sort of flooding in her area was more probable, than a protective measure, such as elevating her house, would have been more attractive to her. If she was a risk taker rather than being risk averse, her utility function would have had a different shape (i.e., it would have been concave rather than convex), and she would be uninterested in insurance or other mitigation measures unless the cost was subsidized.

Recent Extensions of Decision Analsyis

Recent extensions of decision analysis have focused on three general topics: (1) incorporating data collection processes, (2) assessing uncertainty of unknown parameters, and (3) expressing preferences. We will consider each of these developments in turn, by extending the previous example.

Data collection processes. The importance of costs of obtaining data under conditions of uncertainty have led to the development of search models. These models purport to explain how individuals behave when they have imperfect or incomplete market information. The objective is to specify the optimal number of price quotations if there is a fee associated with collecting information from each seller. This fee can be interpreted as the time and effort required to obtain this estimate.

In the previous example, suppose that Ms. Waterman was considering the possibility of elevating her house on stilts, but did not know how much this structural modification would cost. By obtaining different estimates, shw would have a clearer idea as to how much she would have to pay. Suppose after the first search, she received an estimate of $2,500. She now has to decide whether it is worthwhile to obtain another estimate, which may be higher or lower than $2,500. If it is lower, then she will have improved her position (assuming that the quality of the job was the same). If the second estimate was higher, she would have wasted time (although she would have gained some information about the nature of prices in the market). The basic question addressed by these search models is "How much search should be undertaken if the decision maker's objective is to maximize expected utility and there are benefits and costs associated with search."[2] In the case of Ms. Waterman, she would have to assess the likelihood of obtaining an estimate lower than $2,500 and balance this potential benefit against the costs of collecting these data.

Assessing uncertainty. In recent years, there has been considerable work that formally incorporates the cost and value of information as a part of the decision process. Through Bayesian analysis, one can revise prior estimates of key quantities on the basis of new data. Furthermore, one can determine whether or not it is worthwhile to collect further information. To illustrate this approach, suppose that Ms. Waterman feels that there is a direct relationship between the height of flooding of the river in her community and the magnitude of damage to her house. When asked what the height of the river is likely to be during the flood season, she gives three estimates with respective probabilities as shown in Table 2. These three estimates refer to the three states of nature (no flooding, minor flooding, or severe flooding) which enabled Ms. Waterman to evaluate the alternative adjustments in Table 1.

Suppose she now decided to consult historical records to obtain a distribution of flood heights of the river over the past fifty years. By combining the new information obtained from this sample with her initial subjective prior estimates, Ms. Waterman could arrive at an updated or posterior estimate. These revised estimates would depend on the distribution of flood height and the confidence that Ms. Waterman places on the data.

Insert Table 2 about here

As should be clear, there is a direct connection between the amount of search which one undertakes and the updating of information from the search. If, for example, Ms. Waterman was convinced that the historical data was an accurate depiction of the current distribution of flood losses, then there is likely to be little incentive for her to incur additional search costs. On the other hand, if she was under the impression that there had been structural changes in the river flow in recent years, then she might want to explore this matter further.

There is a growing literature which explicitly addresses the question as to the relationship between search costs, the updating of prior information and the choice of a final alternative (see, e.g., Howard, Matheson & Miller, 1976).

Expressing preferences. Individuals may also be concerned with tradeoffs between more than one attribute when expressing their preferences. For example, suppose that in choosing between the adjustments in Table 1, Ms. Waterman is concerned not only with the financial expenditures both prior and after a flood, but also with the time required to undertake each of the adjustments. Models have been developed to incorporate multiple dimensions of concern. For example, the utility associated with different time delays can be evaluated in much the same manner as the utility of money. The alternatives can then be evaluated by constructing a multiobjective value function which reflects Ms. Waterman's tradeoffs between time and cost.

As one adds additional attributes and considers more adjustments, the data collection and computational process becomes more burdensome to the individual. Keeney and Raiffa (1976) discuss ways of simplifying this process, but point out that there may be, nevertheless, substantial costs in obtaining the relevant data in complex decision problems.

Behavioral Approaches

The concept of bounded rationality developed by Herbert Simon (1959) forms the basis for behavioral approaches to individual decision making under conditions of uncertainty. In contrast to decision analysis, this approach seeks to understand what factors actually influence people's decision processes. The underlying philosophy is that the time and energy required to collect information, coupled with the decision maker's cognitive limitations, lead a person to construct a simplified model of the world that differs in important ways from the models employed by decision theorists.

An important feature of this simplified world is a strong tendency toward maintaining the status quo unless there is sufficient motivation for change. Rather than making the tradeoffs between the costs and benefits of searching for new options a person is likely to avoid addressing the question, "What else can I do?" unless the current position is believed to be unsatisfactory.

In cases where alternative options are presented and the decision maker has to make a choice, simplifying strategies are likely to be used. One such behavioral strategy is elimination by aspects (Tversky, 1972). Each alternative is viewed as a set of aspects or attributes and each aspect is weighted according to its relative importance in relation to the others in the set. The higher the weight, the more likely the aspect will be selected for consideration. All the alternatives which do not contain the particular aspect are eliminated from consideration. The process continues until only one alternative remains.

To illustrate the elimination by aspects model, consider the alternatives listed in Table 1 plus the alternative of flood-proofing whereby the base of the structure is protected from minor flooding by a retaining wall or siding material. Table 3 depicts the four aspects of choice, namely, the nature of the activity, time required to obtain information, predisaster and postdisaster costs, and their characteristics for each of the five adjustments. The first two modify the vulnerability of the event (i.e., reduce the potential damage) while the other two distribute losses (i.e., relieve the financial burden after a disaster).[3]

Insert Table 3 about here

For the other three aspects or attributes we have assigned high, medium or low values. We have also assigned importance weights which sum to 1, to indicate how critical each aspect is to the decision maker. At the bottom of each column, we have listed the desired state for each aspect. An individual would thus prefer an alternative which modified the event, had a low predisaster cost and a medium-low, postdisaster cost and required low-medium time to adopt. Obviously no alternative in this set satisfies all four of these aspects. Hence, the order in which one selects the attributes becomes critically important in the final selection process. Figure 4 illustrates two sequences of selecting the attributes and the resulting differences in final choice. In Process 1, the nature of activity aspect is selected first and then "predisaster cost." In Process 2, the two aspects selected are "predisaster cost" and "postdisaster cost," so the final choice is now different.

Insert Figure 4 about here

It should be obvious from the above example that the elimination by aspects method is not optimal (i.e., does not always maximize expected utility). Its major weakness is that it may eliminate alternatives at an intermediate stage in the process whose overall quality is actually greater than those options remaining. It is used by decision makers because it is easy to state, defend and apply.

Tversky (1979) has extended the elimination by aspects approach by suggesting that for many problems there is a natural order associated with attributes which enables one to build preference trees rather than selecting an attribute at random. For example, an individual may first focus on predisaster cost being medium or low because he or she is constrained by short-run budget limitations. Only later would the other three elements of the problem be considered. To illustrate this approach, Process 2 in Figure 4 would represent one of the possible preference trees while Process 1 would not (because it focuses first on the nature of the activity). This approach can be looked at as setting an agenda for the decision maker. As the agenda or order of introducing different attributes varies, the choice will also vary. We will return to this point again in our discussion of public decision making.

If there are a number of alternatives for consideration and relatively few aspects, it is likely that at the conclusion of the above sequential process, several alternatives will still remain. In this case, the decision maker may want to utilize more sophisticated approaches, such as decision analysis, to choose between options. Payne (1976) observed such a two-stage process in people's choice process among students choosing among apartments in experimental studies. Unsatisfactory apartments were first eliminated based on certain criteria, after which a more thorough evaluation was undertaken for choosing between the reduced set of alternatives.

A similar process was observed by White, Bradley and White (1972) in their study of the choice of water sources by East African households.

In many of the communities studied, the women rarely considered more than five alternative sources for water. Rather than searching for a particular "best" source, the women discarded options that were unsuitable on one or more criteria. For example, potential sources were eliminated because the perceived quality of the water was deemed unsuitable or because the energy cost associated with obtaining the water was viewed as too high. Other factors which were considered important were the technological means associated with drawing the water and a social element, that is, a concern with meeting or avoiding certain individuals who frequented a particular water source. Even after a set of alternative sources were rejected, there still may have been more than one source remaining. At this stage of the choice process, the East African women were more likely to trade off one attribute against another (e.g., quality of water with energy cost) in making their final decisions.

According to White, Bradley and White, the decision process utilized by the East African peasants was lexicographic in nature. In this approach, each attribute is ranked in the order of its importance and a prespecified standard is set. All alternatives which did not meet a given standard are deemed unsatisfactory. In contrast to elimination by aspects, the lexocographic model of choice assumes that there is a fixed prior ordering of attributes so that the choice process is deterministic once this set of priorities is known. To illustrate, assume that the East African household ranks quality, technological difficulties and energy costs in that order. In other words, this particular decision rule would choose the source which had minimum energy costs, but met minimum quality standards and technological constraints. If no alternative met the minimum quality constraint, then the criterion would have to be lowered until at least one option satisfied it. If no source met the technological constraints, then the one which came closest to doing so would be chosen. Individuals may decide to order attributes in different ways depending on their specific preferences. Thus, an individual who wants to avoid certain people at all costs might choose social relationships as his first attribute and only consider sources which were not frequented by those people.

Recent Extensions of Behavioral Approaches

In recent years, descriptive models have been investigated through field surveys and laboratory experiments. This work can be categorized under the same three general problem areas that have guided recent research in extending decision analysis. These areas, data collection processes, assessment of uncertainty, and the expression of preferences are considered below.

Data collection processes. Research in this area has focused on the factors which influence the decision to collect data and the sources of information under conditions of uncertainty. Laboratory experiments on insurance decisions (Slovic et al., 1977) have shown that people are often unwilling to protect themselves against events with a low probability of occurrence (e.g., 1 in 1,000) even though the potential loss from the event would be relatively high (e.g., $1,000) and insurance was actuarilly fair (e.g., $1) or even subsidized ($.90). These results suggest that in some situations, people are not inclined to worry about the potential losses from a future disaster if they perceive its probability to be below some threshold. The threshold concept assumes that there are only so many things in life an individual can worry about. People are forced to restrict their attention to events that they feel are sufficiently probable to warrant protective action.

Most low probability events involve the type of transactions where, in addition to price, an individual's behavior is influenced by nonmarket forces such as media exposure or advice from friends and neighbors. Some of these features have been captured by a sequential model of choice which has been examined using data from a field survey of 3,000 homeowners residing in hazard-prone areas (Kunreuther et al., 1978a). According to this model, a person is reluctant to collect data on protection against hazards unless motivated to do so by some external event such as a recent disaster. Even then, the person may only seek information from easily accessible sources. Such a sequential model of choice suggests that individuals fail to protect themselves because of limited knowledge rather than unattractive cost-benefit considerations. The sequential model describes how different environmental events and behavior of other people affect individual action.

Evidence from the social sciences forms the basis for this sequential model of the data collection process. A series of cross-cultural field surveys summarized by White (1974) and Burton, Kates and White (1978) reveal the limited ability of individuals to deal with information about natural hazards. In the latter book the three geographers characterize individual behavior related to hazard adjustments by postulating that the choice process does not begin unless a first threshold of awareness of actual or anticipated loss is reached. The authors suggest the importance of past experience in triggering this awareness. With respect to the diffusion of information there is a large empirical literature on the diffusion of innovations (see Rogers & Schoemaker, 1971) which consistently shows that most individuals are first made aware of a product or of a protective mechanism through the mass media. Before purchasing the item they are likely to turn to friends or neighbors for additional data which may not have been available to them from initial sources of knowledge.

Personal communication may also be a particularly important source of information because there is a tendency to implicitly trust the judgment of a friend or colleague. In addition, accepting the judgment or advice of friends develops and strengthens social relationships which are viewed as desirable ends in themselves. After discussing a new product with someone who has adopted it, one is likely to feel that this person has carefully evaluated the information on which to base a decision. By making such an assumption, which may not necessarily be correct, an individual considering the purchase of a new product can justify not having to collect detailed information.

Further light has been shed on the accuracy of people's perception of risk by Kunreuther et al. (1978b). When homeowners participating in the field survey were asked to estimate the chances of a severe flood or earthquake damaging their property in the next year, 15 percent of the respondents in flood areas and 8 percent of those in earthquake areas were unable to provide any sort of estimate. Of those who did respond, some thought the probability of a disaster hitting them next year was quite large--at least one chance in ten--yet they said they had purchased no disaster insurance even though they knew it was available. Others believed the chance of a disaster affecting them was miniscule--1 in 100,000--yet they had purchased disaster insurance. These findings raise the question as to how well individuals understand the concept of probability or know how to incorporate it into their decisions. It also suggests that there may be other factors influencing choices which are not evident to researchers.

Assessing uncertainty. Efficient adjustment to natural hazards demands an understanding of the probabilistic character of natural events and a desire to think in probabilistic terms. Because of the importance of probabilistic reasoning to decision making in general, a great deal of recent experimental effort has been devoted to understanding how people perceive, process, and evaluate the probabilities of uncertain events. Although no systematic theory about the psychology of uncertainty has emerged from this descriptive work, several empirical generalizations have been established. Perhaps the most widespread conclusion is that people do not follow the principles of probability theory in judging the likelihood of uncertain events. When estimating probabilities, people rely on mental strategies (heuristics) that sometimes produce good estimates, but all too often yield serious biases (Slovic, Kunreuther & White, 1974; Tversky & Kahneman, 1974).

Some of the most dramatic demonstrations of these sorts of biases come from a series of laboratory experiments conducted by Tversky and Kahneman (1974). One heuristic documented in these studies is that of availability, according to which one judges the probability of an event (e.g., a severe flood) by the ease with which relevant instances are imagined or by the number of such instances that are readily retrived from memory. Any factor which makes a hazard highly memorable or imaginable--such as a recent disaster or a vivid film or lecture--could increase the perceived risk of the hazard. According to this bias one would expect that personal experience with misfortune would play a key role in an individual's estimate of the probability of a future disaster.

There are extensive field data indicating that the risks of natural and other hazards are misjudged in ways predictable from laboratory research. For example, the biasing effects of availability are evident in the observations of Kates (1962, p. 140):

> A major limitation to human ability to use improved flood hazard information is a basic reliance on experience. Men on flood plains appear to be very much prisoners of their experience . . . . Recently experienced floods appear to set an upward bound to the size of loss with which managers believe they ought to be concerned.

Kates further attributes much of the difficulty in achieving better flood control to the "inability of individuals to conceptualize floods that have never occurred" (p. 92). He observes that, in making forecasts of future flood potential, individuals "are strongly conditioned by their immediate past and limit their extrapolation to simplified constructs, seeing the future as a mirror of that past" (p. 88). In this regard, it is interesting to observe how the purchase of earthquake insurance increases sharply after a quake, but decreases steadily thereafter, as the memories become less vivid (Steinbrugge, McClure & Snow, 1969).

Some hazards may be inherently more memorable than others. For example, one would expect drought, with its gradual onset and offset, to be much less memorable, and thus less accurately perceived, than flooding. Kirkby (1972) provides some evidence for this hypothesis in her study of Oaxacan farmers. Kirkby also found that memory of salient natural events seems to begin with an extreme event, which effectively blots out recall of earlier events and acts as a fixed point against which to calibrate later points. A similar result was obtained by Parra (1971), studying farmers in the Yucatan. Parra found that awareness of a lesser drought was obscured if it had been followed by a more severe drought. He also observed that droughts were perceived as greater in severity if they were recent and thus easier to remember.

Additional demonstrations of availability bias come from studies by Lichtenstein, Slovic, Fischhoff, Layman and Combs (1978) which showed that frequencies of dramatic cases of death such as accidents, homicides, botulism and tornadoes, all of which get heavy media coverage, tend to be greatly overestimated. In contrast, the frequencies of death from unspectacular events, which claim one victim at a time and are common in nonfatal form (e.g., asthma, emphysema, diabetes) are greatly underestimated. A follow-up study by Combs and Slovic (1979) showed that these biases in judgment were closely related to the amount of coverage given to the various causes of death by the news media.

One would expect that since people have a great deal of difficulty thinking about uncertainty, they would tend to view the world as more certain than it is. Evidence supporting this hypothesis comes from the work of Kates (1962) who found that flood plain dwellers used a number of mechanisms for dispelling uncertainty, such as either denying the risks from flooding or perceiving floods as repetitive or cyclical phenomena.

Expressing preferences. Once the consequences of a decision have been enumerated and their uncertainty assessed, some value must be attached to them. When it comes to tradeoffs between such issues as deaths today vs. deaths in the future or between economic development and possible catastrophic natural disasters, we have little choice but to ask people for their opinions. Unfortunately, for such unfamiliar and complex issues, people may not have well-defined preferences. Fischhoff, Slovic, and Lichtenstein (1980) show that values may often be incoherent, not thought through. For example, in thinking about risk, we may be unfamiliar with the terms in which issues are formulated (e.g., social discount rates, miniscule probabilities, or megadeaths). We may have contradictory values (e.g., a strong aversion to catastrophic losses of life and a realization that we are not more moved by a plane crash with 500 fatalities than one with 300). We may occupy different roles in life (parents, workers, children) which produce clear-cut but inconsistent values. We may vacillate between incompatible, but strongly held, positions (e.g., bicycles are an important mode of transportation, but are too dangerous to be allowed on most streets). We may not even know how to begin thinking about some issues (e.g., the appropriate tradeoff between the opportunity to dye one's hair and a vague, minute increase in the probability of cancer twenty years from now). Our views may undergo changes over time (say, as we near the hour of decision or the consequence itself) and we may not know which view should form the basis of our decisions.

In such situations, where we do not know what we want, the values we express may be highly labile. Subtle changes in how issues are posed, questions are phrased and responses are elicited, can have marked effects on our expressed preferences. The particular question posed may evoke a central concern or a peripheral one; it may help clarify the respondent's opinion or irreversibly shape it; it may even create an opinion where none existed before.

Three features of these shifting judgments are important. First, people are typically unaware of the potency of such shifts in their perspective. Second, they often have no guidelines as to which perspective is the appropriate one, and finally, even when there are guidelines, people may not want to give up their own inconsistency, creating an impasse (Lichtenstein & Slovic, 1973; Tversky & Kahneman, in press).

Summary

Behavioral research depicts the process of choice to be one based on incomplete and often biased information and simplistic decision rules for evaluating alternatives. Studies have shown that one's decisions are typically guided by past experience or personal discussions with other people rather than by a detailed comparison of the costs and benefits of different alternatives.

From a policy perspective, decision analysis is neutral with regard to the optimal locus of decision making. In contrast, those who have been influenced by behavioral analysis contend that people may not act in their own best interest because of limited or biased information. They argue that if there are major societal costs which are incurred because of "poor" decisions by individuals, some form of regulatory control may be necessary. Thus they would favor land use regulations if it was found that individuals were not sensitive to the hazards they faced. They would also support some form of required insurance if empirical data revealed that individuals were not willing to protect themselves voluntarily (e.g., the Flood Disaster Protection Act of 1973, which required all new homeowners to purchase flood insurance as a condition for a federally financed mortgage). We will elaborate on these policy implications in the concluding section where we discuss guidelines for future research.

II. Public Decision Making

The broad area of hazard and resource management frequently requires investments in projects such as flood control dams which affect large numbers of individuals. These public goods have two principal characteristics which differentiate them from products offered on the market such as insurance, flood proofing materials or wooden pilings for elevating one's house. The costs are so high and the individual gets such a small share of the benefits that he or she has no incentive to purchase it. Furthermore, an individual will benefit when others provide the goods, so there is no incentive to pay for it. For example, if half of the community paid for a flood control dam the other half would still be given the same protection. One of the main justifications for the existence of government programs in hazard and resource management is to provide citizens with such public goods as highways, national defense and flood control projects that would not otherwise be provided by the public sector.

In this section we will examine alternative approaches for dealing with the allocation of limited governmental funds among competing projects. Until recently benefit-cost analysis has been the principal tool employed in this process and we will review its concepts first. White has been one of the leaders stressing the importance of including multiple objectives explicitly in the analysis andwe will indicate the types of models of choice which come under the broad heading of multi-objective planning. Finally, there has also been considerable interest by White and others in behavioral questions on how existing institutions as well as disasters and crises affect public decision making. We will conclude this section by touching on work in this area.

Benefit-Cost Analysis

Benefit-cost analysis systematically incorporates tangible and intangible benefits and costs of different projects in much the same way as decision analysis does. The decision maker lists a set of alternative options, and then determines possible outcomes under different states of nature. The alternative which produces the greatest net benefit (total benefit minus total costs) is considered the most desirable one. The tool was originally utilized in evaluating water resource projects in the 1930's but it has had widespread use only since World War II.

To illustrate the application of benefit-cost analysis, consider the decision by the Corps of Engineers as to whether they should invest in flood control Project A or B on a given river basin. In order to determine the expected benefits from each project, they have computed the expected annual savings in flood damage (i.e., probabilities times damages avoided from building the dam) to the community for the next fifty years appropriately discounted to the present.[4] Similarly, the costs of each project are discounted to the present year so an appropriate comparison can be made.[5] A summary of the relevant figures appears below in Table 4. As we can see from these values, Project B has a higher net benefit to society but assists primarily the upper income group. Project A protects primarily low income individuals who comprise the flood plain.

Insert Table 4 about here

The above example does not distinguish between the benefits from each of the projects accruing to the federal government and to the local community and hence ignores cost-sharing issues. The importance of making this distinction can be illustrated by two contrasting examples of disaster programs. Suppose federal disaster relief or subsidized flood insurance provides recovery funds for a substantial portion of flood losses; then the construction of a project will mean a reduction in federal disaster expenditures. If, on the other hand, flood victims in a community rely on their own resources for recovery, then the federal government stands to gain little financially from a flood control project. In the latter case, potential victims may want to place pressure on their local government to help build the project with their own funds. The issue of cost-sharing between federal and local governments thus has important implications for efficient resource development. Until recently, agencies like the U.S. Corps of Engineers required relatively little cost-sharing by local governments for large flood projects, but specified higher percentages for other techniques such as channel improvements, levees and diversion channels. Marshall (1970), who analyzed data for 34 Crops projects authorized by the 1968 Flood Control Act, found that the local cost sharing ranged from 0 percent for large reservoirs to approximately 50 percent for some levees and channel improvements. There was considerable variance in the cost-sharing amounts for the same type of projects in different regions of the country.[6]

One of the important current issues in cost-benefit analysis is the proportion of costs that local interests should be required to absorb for specific projects. Marshall (1973) has shown that an association rule, whereby local beneficiaries are charged a percent of the cost share equal to the ratio of marginal local benefits to marginal national benefits computed at the nationally efficient scale of output, induces local interests to select the nationally efficient project design. Furthermore, he points out that there needs to be consistency between the cost-sharing practices of different agencies as well as between different techniques such as structural and non-structural measures.

On a theoretical level, this type of analysis makes excellent sense. The challenge from the point of view of evaluating alternative cost-sharing rules is determining what the national and local benefits are likely to be for different types of projects, and understanding how local constituencies decide on whether they will sanction a particular project given a fixed percentage of cost they must assume. There is thus a need to understand the decision processes of governmental units and to collect detailed information on the effects of different actions before deciding on a particular course of action.

Multi-Objective Planning

One of the principal criticisms leveled at benefit-cost analysis is that is focuses almost entirely on economic efficiency criteria without concern for other objectives such as income redistribution (Maass, 1965). One way of coping with equity considerations is to utilize other means such as transfer payments to low income residents rather than explicitly incorporating other objectives into the analysis. In the above example, Project B would still be deemed most desirable and special grants from tax-payers' money could be given low-income flood victims.

An alternative approach is to incorporate explicitly income distribution and other goals of a particular project as part of a multicriterion objective function. White and his colleagues on the Committee of Water (1968) went to great lengths to highlight the diverse objectives which must be taken into account when planning for water management of the Colorado River. Aside from the standard national economic efficiency goal, four other aims were suggested: (1) income redistribution, (2) political equity,

(3) controlling the natural environment, and (4) preservation and aesthetics. The report indicated the nature of these different objectives, but left it to the policy maker to determine how tradeoffs between them should be made.

This concern with incorporating multiple objectives into analyzing resource management projects was expressed by the U.S. Water Resources Council (WRC) who in 1973 adopted principles and standards which indicated that the beneficial and adverse effects of projects be assessed under four general accounts: national economic development (NED), environmental quality (EQ), regional economic development (RED), and social well being (SWB). The 1979 WRC Principles and Standards for Planning Water and Land Resources emphasized the importance of evaluation of NED and DQ and then provided detailed guidelines for quantitatively measuring the beneficial and adverse effects of each of these two objectives. The document, however, notes that "the statement of the objectives and specification of their components in these standards is without implication concerning priorities to be given to them in the process of plan formulation and evaluation" (p. 72981).

Considerable effort has been spent over the past twenty years on ways that a multicriterion objective function can be evaluated by a policy maker in a systematic manner. After stating the objectives of the policy proposal, one has to define attributes which can measure how well each alternative meets specific objectives. For example, one attribute measuring NED might be "number of new jobs created." There are likely to be several attributes which map onto each objective. In the case of qualitative objectives, it may be more difficult to define a set of attributes. For example, how does one measure "environmental quality" in a quantitative manner? One way to get a handle on this objective is to divide it into subobjectives (e.g., creating recreational opportunities, preserving wildlife) which may then suggest specific attributes (e.g., number of visitor days in a park).

If there are several attributes describing a given objective, then appropriate weights must be given to them. If the attributes are independent of each other then one estimates the utility function for each attribute separately in a manner similar to that described in the previous section (see Figure 1). One then determines scaling constants to specify the appropriate weights in the overall objective function. The process is somewhat more complex if attributes are dependent.[7] It is questionable how well the process is likely to work in practice. It requires a considerably sophisticated policy maker and does not explicitly incorporate the decision processes of different individuals and stakeholders.

A related approach is goal programming whereby the policy makers set specific desired goals for particular objectives and a penalty function associated with deviating from these goals. It is then possible to develop a formal model for evaluating the impact of different alternatives on the multi-criterion objective function. In essence, this approach is a hybrid between a lexicographic model and a multi-attribute utility model. Acceptable levels are set as in a lexicographic approach but deviations below this level and simultaneous consideration of alternatives take place as in a multiattribute utility model. There is still an open question as to how different weights should be determined for the different goals and whether such a multi-objective function captures the decision process.[8]

An alternative theory of measurement has recently been proposed by Saaty (1977). His methodology consists first of decomposing the problem into relevant attributes and then combining them to make an overall choice. Rather than asking individuals to estimate utility functions for each attribute he only requires them to make pairwise comparisons which can be combined in a way that reflects the decision makers' preferences. For example, consider the five objectives for the Colorado River project investigated by White and his Committee on Water. The policy analyst would have to make ten pairwise comparisons across those objectives which reflected the relative importance he attached to each one in relation to another. For example, the analyst would be asked to specify the importance of the national economic efficiency goal relative to income redistribution; the income redistribution goal relative to preservation and esthetics; and so forth. If each objective was subdivided into a set of attributes, a similar set of comparisons would have to be made at this level.

Multiattribute utility models, goal programming and Saaty's scaling method assume that there is a single decision maker who must determine a course of action based on his or her estimates of appropriate weights and utilities. If there are several interest groups represented (e.g., the flood plain resident, the general taxpayer, representatives from different state, federal and local agencies) then each one is likely to have their own rankings with respect to the importance of different attributes and objectives. Either some type of weighting scheme has to be assigned to the preferences of each of these different interest groups or some type of consensual procedure such as a nominal group and delphi processes[9] must be employed.

Understanding Public Decision Making

On the descriptive side there has been an interest in understanding the impact of different institutional arrangements and specific events such as disasters on public policy formulation. White (1969) indicates that there are three principal ways that state and federal agencies can gauge people's attitudes toward possible solutions to their problems. The public hearing is most democratic, permitting citizens' groups, industries and other special interests to state their points of view. A second method is Congressional committee hearings which are held as part of budget agency recommendations or for determining the need for special legislation. White feels that by far the most important sources of public preferences are the informal comments from different citizens' groups, lobbyists and other interested parties. The role of personal contact and informal networks in influencing strategies and final courses of action have a parallel in the studies of the individual decision making process where friends and neighbors play a key role in influencing choice.

Although the above three institutional arrangements provide insight into how information is elicited by public agencies, they do not indicate how the actual choice process is made. One of the most interesting studies on this question was a description of the decision making process used by the Delaware River Basin Commission in their analysis of water quality on the Delaware River (Kneese & Bowar, 1968; Haefele, 1973). A system of advisory committees provided estimates of costs and benefits of five different alternatives with respect to water quality. These five alternatives (one of which was the status quo) were then presented at a public hearing where different groups were able to voice their concerns and state their preferences. Finally, the actual choice decision was made by an interstate compact with three state commissioners, each having one vote. After considerable discussion, the commission chose water quality standards falling somewhere between the two choices favored by almost everyone at the public hearings.

The Delaware River Basin Commission study on water quality utilized existing institutional mechanisms to evaluate the benefits and costs of a set of alternatives. Furthermore, there was general agreement by all parties as to what were the preferred alternatives. One reason for this is that the benefits of improved water quality were restricted solely to the recreation option.

When there are a number of projects to be considered and a number of different attributes are relevant, then the decision making process may be somewhat more complicated than the one followed by the Delaware River Basin Commission.[10] In this case, the ordering of different attributes, or more generally the construction of an agenda, may play a key role in the final decision. We have already discussed this point in the section on individual decision making by indicating how descriptive techniques such as elimination by aspects or preference trees will yield different choices depending on which aspects are chosen first. Similar results have been shown to hold for group decision processes where changes in the agenda have influenced outcome processes.

One of the most interesting recent studies to explore agenda effects was by Plott and Levine (1978) who demonstrated that one could change the probability that certain types of planes would be purchased by a flying club by altering the order in which aspects pertinent to the decision were considered. They also replicated their results in a series of laboratory experiments. A simple example in the water resources area illustrates the importance of agenda setting on decisions. Suppose that a committee is deciding which water resources projects to fund and is considering two regions (Florida and Louisiana) and whether project costs should exceed B dollars. One agenda might determine the set of available projects by initially focusing on cost and then on location. Another agenda would reverse the order. The group choice may yield a different solution depending upon which question is presented first.[11]

Frequently the agenda is ordered by external events such as disasters or crises which focus attention on specific remedies. White and Haas (1975) point out that most Federal legislation on natural hazards follows within a few months or a year of a major disaster. The history of the flood insurance program illustrates this point.[12] Severe flooding in the northeastern states in 1955 created a clamor among victims for a government-backed insurance program. As a result, Congress passed the Flood Insurance Act of 1956 which provided for government subsidized rates, but Congress refused to appropriate the funds for the program because there were serious questions raised both within government and by outsiders as to the potential harmful effects on flood plain development of instituting a uniform set of premiums by river basins.

Two fortuitous events helped to launch the National Flood Insurance program. The Bureau of the Budget appointed a Task Force on Federal Flood Control Policy which explicitly recognized the need for a different type of flood insurance program and indicated how such coverage could be related to other types of adjustments such as land use regulation. At approximately the same time, Hurricane Betsy devastated a large portion of the Gulf Coast including New Orleans. As a result, a Congressional task force was authorized to undertake a study on the feasibility of some form of federal flood insurance. The results of this study, coupled with the Task Force Report, culminated in the National Flood Insurance Act of 1968.

The most recent change in the flood insurance program was triggered by Tropical Storm Agnes in 1972. Many communities struck by these disasters had not entered the flood insurance program, and hence residents could not buy coverage. In other communities where flood insurance was available (including Wilkes Barre) few residents had voluntarily purchased coverage. This lack of voluntary interest in the program on the part of homeowners and communities induced Congress to pass the Flood Disaster Protection Act of 1973. which required insurance as a condition for any mortgage or home loan partially or fully financed by the federal government.

This brief summary of the impact of flood disasters on insurance policy suggests a behavioral model of choice for public decision making which has similar features to the sequential model for individuals:

Stage 1--Awareness of the problem. This is frequently triggered by a disaster with its resulting inequities or by some concern by Congress in reviewing the performance of a given program.

Stage 2--Examination of feasible alternatives. Through a task force report and/or public hearings, a set of options is outlined for possible adoption.

Stage 3--Choosing an option. Either the proposed program is rejected because its costs are likely to exceed its benefits (Federal Flood Insurance Act of 1956) or the program is adopted (National Flood Insurance Act of 1968).

Stage 4--Reevaluation of choice. Should the program be unsuccessful in meeting its objectives, then it will be reexamined. Policy makers are then made aware of a problem and have reentered Stage 1. The reexamination of the Flood Insurance Program after Tropical Storm Agnes illustrates this phase of the process.

Future Research Directions

Our survey illustrates the motivating forces behind the alternative approaches to decision making under uncertainty. Tools such as decision analysis and cost-benefit analysis are primarily concerned with ways to improve behavior, hence they are *prescriptive* in nature. Behavioral analyses look at how the world *actually* works, hence the concern with institutional arrangements and decision processes. These approaches are *descriptive* in nature. White would like to see policies designed with sensitivity to both prescriptive and descriptive considerations. It is in this spirit that we will offer a few suggestions for future research in the two broad areas surveyed above.

Individual Decision Making

In the area of individual decision making, we need to develop techniques for structuring the decision problem. The logic of decision analysis cannot be applied until the alternatives, critical events, and outcomes are specified. We need algorithms for accomplishing this and for simplifying the large, complex decision trees that may result. Crisis situations, where stakes are high, time is short, and the alternatives and information are continually changing, pose particularly difficult structuring problems.

Subjective judgments of probability and value are essential inputs to decision analyses. We still do not know the best ways to elicit these judgments. Now that we understand many of the biases to which judgments are susceptible, we need to develop debiasing techniques to minimize their destructive effects. Simply warning a judge about a bias may prove ineffective. Like perceptual illusions, many biases do not disappear upon being identified. It may be necessary to (a) restructure the judgment task in ways that circumvent the bias, (b) use several different methods allowing opposing biases to cancel one another, or (c) correct the judgments externally, based on an estimate of the direction and strength of the bias.

Much progress has been made recently toward understanding judgmental and decision making processes. We need to continue this pursuit of basic knowledge. Simon (1965, p. 92) outlining the historical development of writing, the number system, calculus, and other major aids to thought, indicates the importance of synthesizing descriptive and prescriptive approaches.

> All of these aids to human thinking, and many others, were devised without understanding the process they aided--the thought process itself. The prospect before us is that we shall understand that process. We shall be able to diagnose the difficulties of a . . . decision maker . . . and we shall be able to help him modify his problem solving strategies in specific ways.
>
> We have no experience yet that would allow us to judge what improvement in human decision making we might expect from the application of this new and growing knowledge . . . . Nonetheless, we have reason, I think, to be sanguine at the prospect.

Public Decision Making

In the document, Water and Choice in the Colorado Basin, White and his colleagues detailed a set of objectives and alternatives for managing the Colorado River Basin. The report offers prescriptive policy suggestions while recognizing the constraints imposed by existing institutional arrangements. Thus, it proposes that a set of plans, which involve structural and nonstructural methods, be developed which explicitly recognizes the objectives of different parties and institutional or cultural constraints which limits the range of choice.

The study of the Colorado River basin provides guidance to policy makers as to how one might develop a strategy for evaluating alternative programs. It does not, however, address the question as to what is likely to emerge from this activity. In this connection, the Federal Flood Loss Reduction Program which was the result of the 1966 Bureau of the Budget task force which White chaired offers a blueprint for a plan of action. The principal recommendation of this task force is that both structural measures such as dams and protection works and nonstructural means (e.g., land use and building regulations, warnings, flood insurance) be considered in coping with flood problems.

Despite the public commitment to this program, there have been severe problems in actually implementing a multiple means strategy. The many agencies involved in the flood problem, conflicting objectives and limited data, have made it extremely difficult to coordinate programs in flood-prone communities. On the positive side, a direct outcome of this task force report was the National Flood Insurance Program with its emphasis on land-use regulations and building codes as a condition for subsidized insurance.

One way to facilitate communication among agencies with a common data base is to develop some form of decision support system for analyzing resource management problems. The term "decision support system" implies the use of computers to:

1. Assist managers in their decision processes.

2. Support, rather than replace, managerial judgment.

3. Improve the effectiveness of decision making.[13]

The key feature of a decision support system is that it enables policy makers and interested users to experiment with alternative sets of scenarios in the confines of their office or agency. The computer plays a key role in facilitating data analysis, standardizing the data bases so that different agencies have common points of communication and enabling relatively easy comparisons of costs and benefits of different programs.

At a descriptive level, a group at the University of Pennsylvania have developed an interactive decision support system for disaster policy analysis in the hopes that it will facilitate the decision and choice process of resource managers (see Kunreuther et al., 1978b). The modeling system can deal with sets of individual homeowners and businesses. This feature enables the user to construct representations of hazard-prone communities and examine impacts of mitigation and recovery programs on inhabitants as well as on external sectors such as federal, state and local governments.

To illustrate the use of decision support systems in a specific problem context, consider the evaluation of alternative flood plain management programs. Any adjustment or combination of adjustments will impact on a number of different stakeholders. Not only are the residents and businesses of the flood plain directly or indirectly affected, but so are the general taxpayers who have to pay part of the disaster bill. Businesses and industrial concerns such as the insurance industry, financial institutions, the construction and real estate industry are also impacted by hazard mitigation and recovery programs.

Figure 5 illustrates the interaction among alternatives and stakeholders affected by particular measures. The first four items represent simple adjustments for dealing with flood plain management; the remaining alternatives would be a combination of several adjustments. We have listed a representative set of stakeholders affected by each of the strategies. The cells in the matrix can be used to indicate costs and benefits of any strategy. For example, a strategy of subsidized flood insurance would involve costs to flood plain residents and businesses in the form of premiums, and benefits in the form of claims following a disaster; the general taxpayer would incur the costs of premium subsidies but would benefit by having to pay for less disaster relief. The private insurance agents would have administrative costs of operating the program but would receive commissions for their efforts. Similarly, governmental agencies such as the Federal Emergency Management Agency (FEMA) would incur program costs, but would help fulfill their responsibility of reducing future flood losses.

The challenge in developing a meaningful flood plain management program is to evaluate data entered in the various cells in the matrix shown in Figure 5 and to utilize criteria for selecting among them. A flexible decision support system enables policy makers to investigate the relative performance of alternative strategies in various situations--such as the 100-year flood. Sensitivity analysis can be performed to determine the impact of different socioeconomic and physical characteristics of the flood prone area or the nature of flooding on the performance of different alternatives. The computer facilitates data analysis, standardizes data bases so policy makers can communicate with each other and contrasts the relative performance of different strategies on different constituencies.

The computer does not provide an answer as to which policy or set of strategies is most desirable for adoption. Rather it is a tool along with cost/benefit analysis and multiobjective planning for enabling policy makers to weigh the tradeoffs among strategies and to arrive at solutions. Policy makers will still have to make relevant value judgments in determining a final course of action.

Decision support systems can also provide users with insights into the impact of other decision makers on their own activities. One of the most interesting recent experiments is the design of a system for allocating public goods among individuals. Ferejohn, Forsythe and Noll (1977) developed an interactive computer model which enabled public broadcasting stations to allocate their budget to different programs based on the actions of others. The more stations which selected the program, the lower the cost to each individual station. After an initial set of program selections, price information on the various programs were disseminated to each individual station and they had an opportunity to revise their choices. Within a relatively small number of iterations a stable solution was found.

The important lesson of this experiment for our purposes is the opportunity of providing decentralized information to resource managers who have to allocate a budget among a number of activities. A similar mechanism for eliciting preferences through prices may lead to more efficient allocation of scarce resources and better coordination between fedreal, state and local agencies facing similar problems. In contrast to the PBS system where there is a budgetary decision which must be made at regular intervals, no specific deadlines force coordination in the area of resource management. By developing an interactive system for communication, there may be opportunities for sharing data and bringing groups facing the same problems to address their budgetary allocation decisions more systematically.

The use of decision support systems for policy making purposes is only as good as the assumptions made by users. In the case of resource management problems which involve a number of interested parties, each having their own objectives, detailed analyses of the impact of different programs have to be made. For such tools to be useful, there must be an explicit recognition of the criteria on which policies must be judged, as well as the constraints under which one is operating. These are the basic ingredients for any choice model, as Gilbert White has stressed in his papers on the subject and in his public service activities. He has been instrumental in awakening public and private decision makers to the need for systematically evaluating different alternatives. The extent to which we can reap the benefits of his efforts rests with our future endeavors.

Footnotes

1. Utility curves are unique up to a linear transformation. Hence, two end points can be arbitrarily specified and the other points on the curve estimated in relation to these two. For an excellent introduction to the properties of utility functions and ways to assess them, see Keeney and Raiffa (1976, Chapter 5).

2. The seminal work in this area is by Stigler (1961). Extensions of the analysis of and a comprehensive set of references on the subject appears in Rothschild (1974).

3. The nature of the activity is based on the classification scheme described by White and Haas (1975). They categorize different measures as either modifying the causes of the hazard (e.g., cloud seeding of a hurricane), modifying the vulnerability to the event (e.g., flood proofing) or distributing losses (e.g., insurance), p. 57.

4. A more extensive discussion of the selection of a discount rate appears in the chapter by Platt in this volume.

5. For purposes of this review, we will not dwell on the detailed calculations of benefits and costs. The water resources area has been the subject of a number of excellent analyses using this technique. See, for example, Krutilla and Eckstein (1958), Hirshleifer, DeHaven and Milliman (1960), and Haveman (1965). A comprehensive summary of the benefit-cost methodology can be found in Herfindahl and Kneese (1974).

6. For example, local cost-sharing on levees ranged from 0% to 49.7% and channel improvements from 7.8% to 54.3%.

7. A more detailed discussion of this process is found in Keeney and Raiffa (1976).

8. Programming approaches for structuring and solving these problems have been developed in the literature (see Dyer, 1972) and have been proposed for solving specific resource management problems (e.g., Charnes, Cooper, Karwan and Wallace, 1979).

9. For a description of these group techniques for program planning see Delbecq, Van de Ven and Gustafson (1975).

10. Russell (1979) contains a set of papers which describe empirical tests of alternative theories of public decision making.

11. A more detailed discussion of the impact that ordering the items has on choice can be found in Plott and Levine (1978).

12. A more detailed description of the Flood Insurance Program and its changes appears in the chapter by Platt in this volume. The discussion here supplements Platt's historical review by calling special attention to the relationship between crises and legislation.

13. This definiton is taken from Keen and Scott-Morton's (1978) book on the subject (p. 1).

References

Burton, I., Kates, R. W. & White, G. The environment as hazard. New York: Oxford University Press, 1978.

Charnes, A., Cooper, W., Karwan, K. & Wallace, W. A chance-constrained goal programming model to evaluate response resources for marine pollution disasters. Journal of Environmental Economics and Management, 1979, 6, 244-274.

Combs, B. & Slovic, P. Newspaper coverage of causes of death. Journalism Quarterly, 1979, 56(4), 837-843; 849.

Committee on Water. Water and choice in the Colorado basin: An example of alternatives in water management. Washington, D. C.: National Academy of Sciences, 1968.

Delbecq, A., Van de Ven, A. & Gustafson, D. Group techniques for program planning. Glenview, Illinois: Scott, Foresman & Co., 1975.

Dyer, J. Interactive goal programming. Management Science, 1972, 19, 62-70.

Ferejohn, J., Forsythe, R. & Noll, R. An experimental analysis of decision making procedures for discrete public goods: A case study of a problem in institutional design. Social Science Working Paper 155. Pasadena: California Institute of Technology, 1977.

Fischhoff, B., Slovic, P. & Lichtenstein, S. Knowing what you want: Measuring labile values. In T. Wallsten (Ed.), Cognitive processes in choice and decision behavior. Hillsdale, N.J.: Erlbaum, 1980, 117-141.

Haefele, E. Representative government and environmental management. Baltimore: Johns Hopkins Press, 1973.

Haveman, H. Water resource investment in the public interest. Nashville, Tenn.: Vanderbilt University, 1965.

Herfindahl, C. & Kneese, V. Economic theory of natural resources. Columbus, Ohio: Charles Merrill, 1974.

Hirshleifer, J., De Haven, J. C. & Milliman, J. W. Water supply. Chicago: University of Chicago Press, 1960.

Howard, R. A., Matheson, J. E. & Miller, K. L. Readings in decision analysis. Menlo Park: Stanford Research Institute, 1976.

Kates, R. Hazard and choice perception in flood plain management. Research Paper No. 78. Chicago: University of Chicago, Department of Geography, 1962.

Keen, P. & Scott-Morton, M. Decision support systems: An organizational perspective. Reading, Mass: Addison Wesley, 1978.

Keeney, R. & Raiffa, H. Decisions with multiple objectives: Preferences and value tradeoffs. New York: John Wiley & Sons, 1976.

Kirkby, A. V. Perception of rainfall variability and agricultural and social adaptation to hazard by peasant cultivators in the Valley of Oaxaca, Mexico. Paper presented at the 22nd International Geographical Congress, Calgary, Alberta, Canada, 1972.

Kneese, A. V. & Bower, B. T. Managing water quality: Economics, technology, institutions. Baltimore: Johns Hopkins Press, 1968.

Krutilla, J. V. & Eckstein, O. Multiple purpose river development. Baltimore: Johns Hopkins Press, 1958.

Kunreuther, H., Ginsberg, R., Miller, L., Sagi, P., Slovic, P., Borkan, B. & Katz, N. Disaster insurance protection: Public policy lessons. New York: Wiley Interscience, 1978 a.

Kunreuther, H., Lepore, J., Miller, L., Vinso, J., Wilson, J., Borkan, B., Duffy, B. & Katz, N. An interactive modeling system for disaster policy analysis. Boulder: Institute of Behavioral Science, 1978 b.

Lichtenstein, S. & Slovic, P. Response-induced reversals of preference in gambling: An extended replication in Las Vegas. Journal of Experimental Psychology, 1973, 101, 16-20.

Lichtenstein, S., Slovic, P., Fischhoff, B., Layman, M. & Combs, B. Judged frequency of lethal events. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 551-578.

Maass, A. Benefit-cost analysis: Its relevance to public investment decisions. Quarterly Journal of Economics, 1966, 80, 208-226.

Marshall, H. Economic efficiency implications of federal-local cost sharing in water resource development. Water Resources Research, 1970, 6, 673-682.

Marshall, H. Cost sharing and multiobjectives in water resource development. Water Resources Research, 1973, 9, 1-10.

Parra, C. G. Perception of past droughts in Ticul, Yucatan. In Proceedings of the Great Plains-Rocky Mountain meeting of the American Association of Geographers, Colorado Springs: AAG, 1971.

Payne, J. W. Task complexity and contingent processing in decision making: An information search and protocol analysis. Organizational Behavior and Human Performance, 1976, 16, 366-387.

Plott, C. & Levine, M. A model of agenda influence on committee decisions. American Economic Review, 1978, 68, 146-160.

Raiffa, H. Decision analysis. Reading, Mass.: Addison-Wesley, 1968.

Rothschild, M. Searching for the lowest price when the distribution of prices is unknown. Journal of Political Economy, 1974, 82, 689-711.

Rogers, E. & Shoemaker, F. Communication of innovations. New York: The Free Press, 1971.

Russell, C. (Ed.), Applying public choice theory. What are the prospects? Washington, D. C.: Resources for the Future, 1979.

Saaty, T. A scaling method for priorities and hierarchical structures. Journal of Mathematical Psychology, 1977, 15, 223-281.

Simon, H. A. Theories of decision making in economics and behavioral science. American Economic Review, 1959, 49, 253-283.

Simon, H. The shape of automation for man and management. New York: Harper & Row, 1965.

Slovic, P., Fischhoff, B., Lichtenstein, S., Corrigan, B. & Combs, B. Preference for insuring against probable small loss: Implications for the theory and practice of insurance. Journal of Risk and Insurance, 1977, 44, 237-258.

Slovic, P., Kunreuther, H. & White, G. Decision processes, rationality, and adjustment to natural hazards. In G. F. White (Ed.), Natural hazards: Local, national and global. New York: Oxford University Press, 1974.

Steinbrugge, K. V., McClure, F. E. & Snow, A. J. Studies in seismicity and earthquake damage statistics. Washington, D. C.: U.S. Department of Commerce Report (Apendix A), COM 71-0053.

Stigler, G. The economics of information. Journal of Political Economy, 1961, 69, 213-225.

Tversky, A. Elimination by aspects: A theory of choice. Psychological Review, 1972, 79, 281-299.

Tversky, A. & Kahneman, D. Judgment under uncertainty: Heuristics and biases. Science, 1974, 185, 1124-1131.

Tversky, A. & Kahneman, D. The framing of decisions and the rationality of choice. Science, in press.

Tversky, A. & Sattath, S. Preference trees. Psychological Review, 1979, 86, 542-573.

U. S. Water Resources Council. Principles and standards for planning water and related land resources. Federal Register, 1979, 44(242), 72,892-72,990.

White, G. The choice of use in resources management. Natural Resources Journal, 1961, 1(March), 23-40.

White, G. Optimal flood damage management retrospect and prospect. In A. V. Kneese & S. C. Smith (Eds.), Water research. Baltimore: Johns Hopkins Press, 1966.

White, G. Strategies of American water management. Ann Arbor: University of Michigan, 1969.

White, G. (Ed.), Natural hazards: Local, national and global. New York: Oxford University Press, 1974.

White, G., Bradley, D. & White, A. Drawers of water. Chicago: University of Chicago Press, 1972.

White, G. & Haas, J. Assessment of research on natural hazards. Cambridge: MIT Press, 1975.

Table 1

Practical Range of Adjustments and Consequences to Ms. Waterman

	State of Nature		
	No Flooding	Minor Flooding	Severe Flooding
Loss	0	-$6,000	-$20,000
Probability	.90	.09	.01
Adjustment:			
Bear Loss Herself	0	-$6,000	-$20,000
Flood Insurance[a]	-$50	-$ 250	-$ 250
Federal Relief[b]	0	-$4,000	-$18,000
Elevating House[c]	-$2,000	-$2,000	-$ 6,000

[a] We are assuming $20,000 coverage at 2.50 per $1,000 and the following deductible schedule -- maximum ($200, 2% of loss).

[b] For illustration purposes, we are assuming a $2,000 forgiveness grant and no low interest loans.

[c] We assume elevating the structure cost at $2,000.

Table 2

Ms. Waterman's Prior Estimates of River Height

	Probability	Event
Less than 35 feet	.90	No Flooding
35-45 feet	.09	Minor Flooding
More than 45 feet	.01	Severe Flooding

Table 3

Four Aspects of Choice

for Evaluating Flood Adjustments

Adjustments	Nature of Activity .3*	Time to Get Information .1*	Predisaster Cost .4*	Postdisaster Cost .2*
Flood proofing	Modify Vulnerability	High	Medium	Medium
Elevate house	Modify Vulnerability	Medium	High	Low
Insurance	Distribute Losses	Medium	Low	Low
Federal Relief	Distribute Losses	Low	Low	High
Desired state	Modify Vulnerability	Low-Medium	Low-Medium	Low

* Importance weight

TABLE 4

EVALUATION OF TWO PROJECTS UTILIZING
BENEFIT-COST ANALYSIS

Project A			
	Benefits		
Sector	Expected Annual Savings in Flood Damage	Project Cost	Net Benefits
Low Income	500		
Middle Income	100		
High Income	80		
	680	600	80

Project B			
	Benefits		
Sector	Discounted Expected Annual Savings in Flood Damage	Project Cost	Net Benefits
Low Income	120		
Middle Income	130		
High Income	400		
	650	500	150

NOTE: All benefits and costs in thousands of dollars.

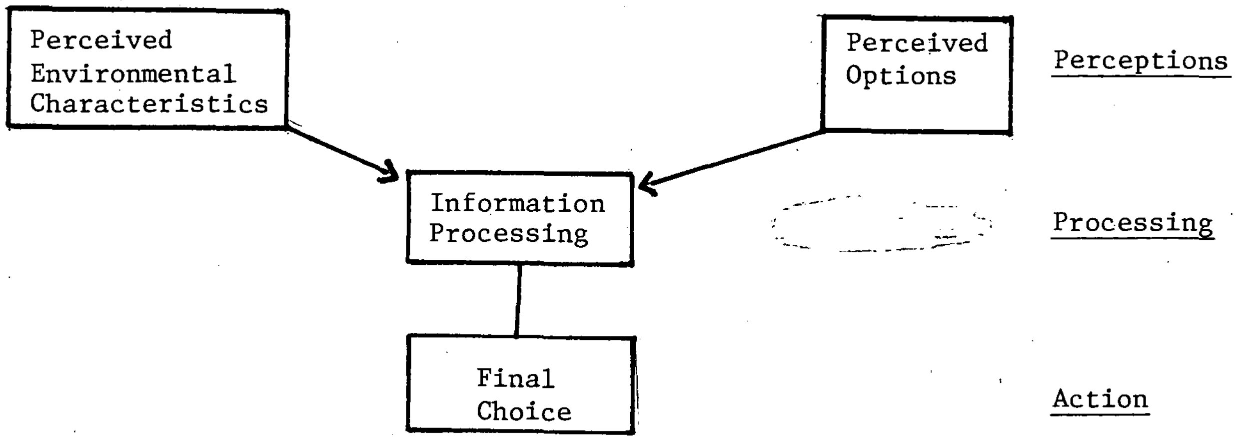

Figure 1. The Decision-Making Process

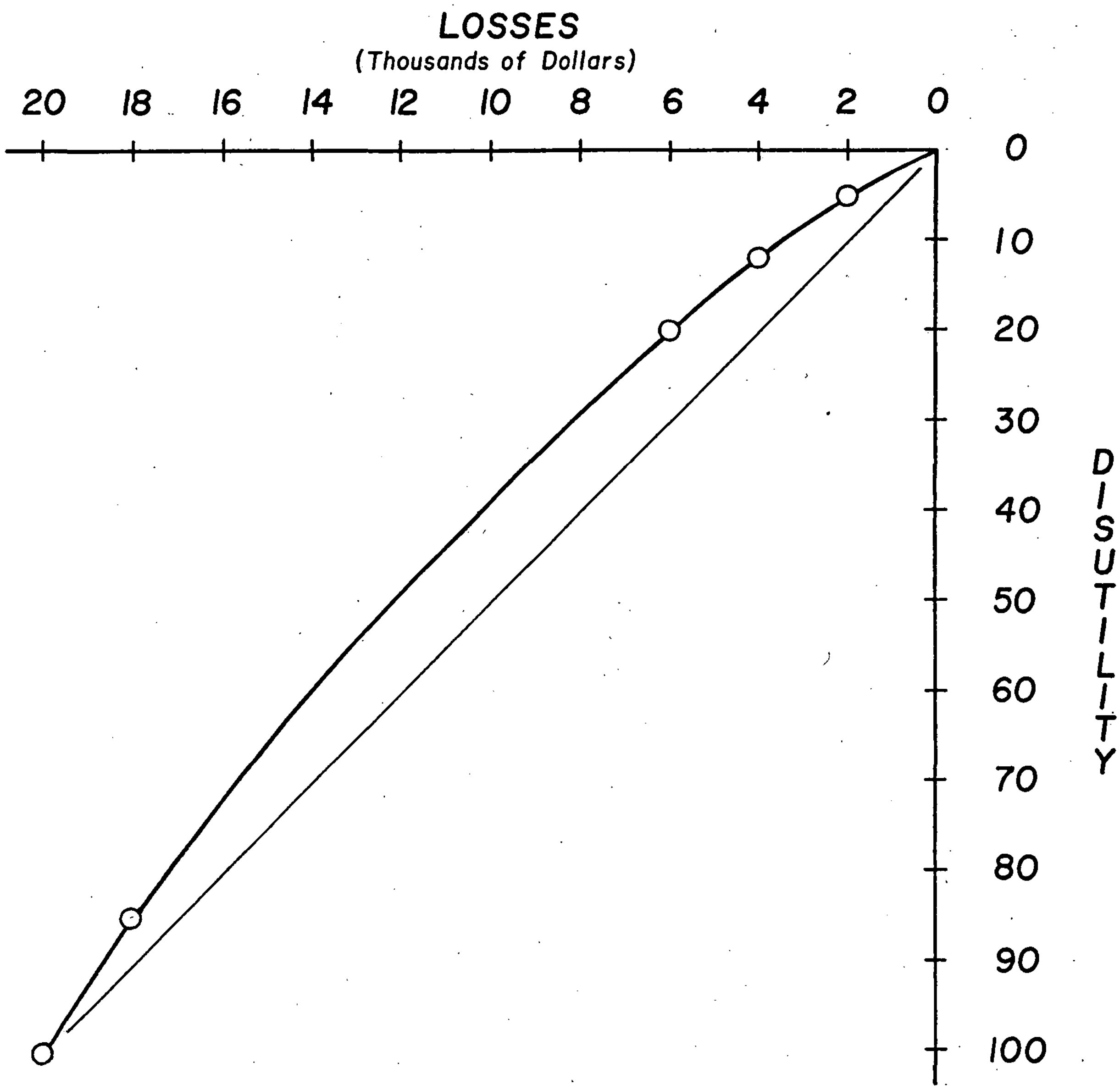

Figure 2. Ms. Waterman's utility function for different losses of money.

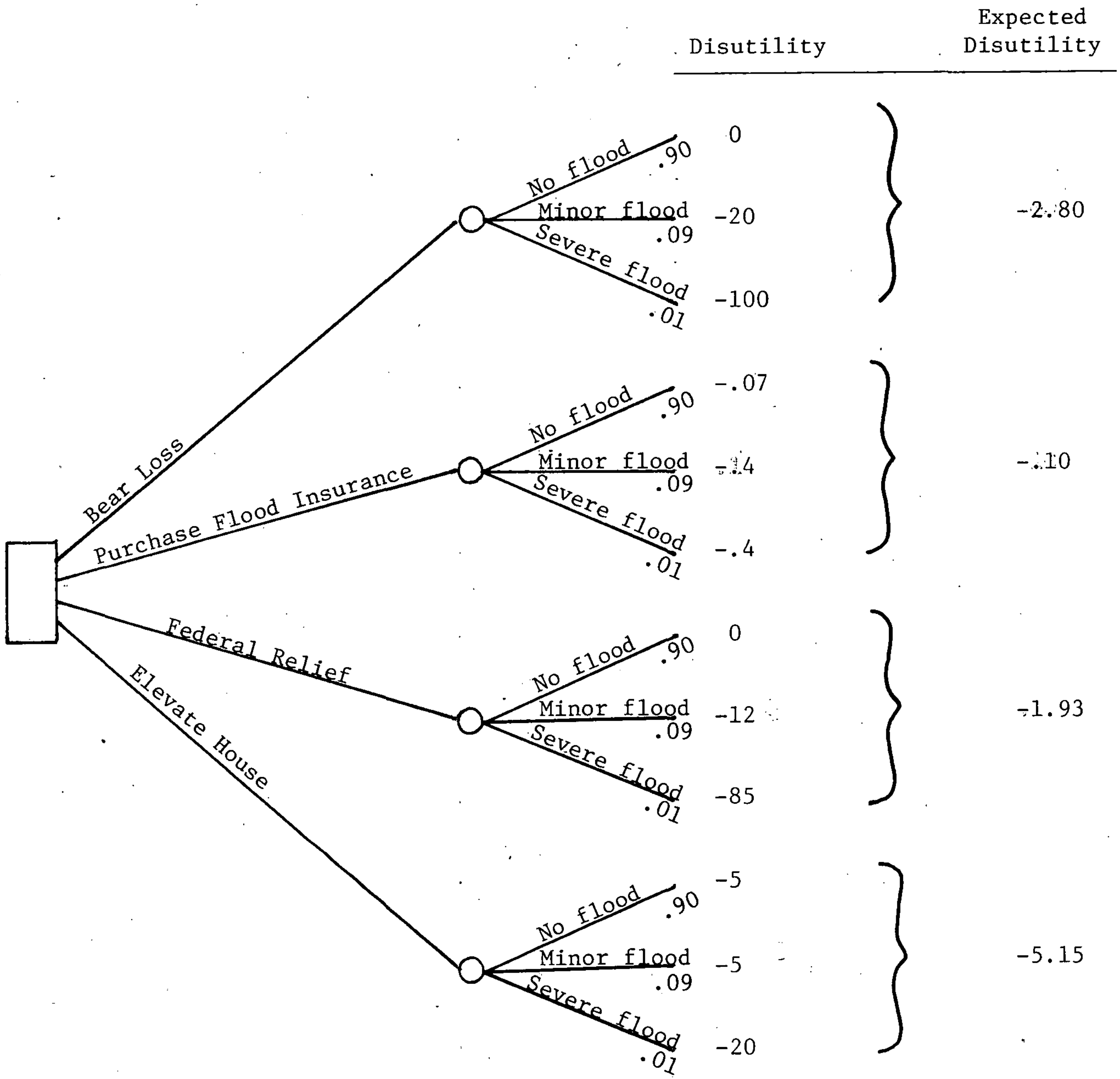

Figure 3. Decision tree for Ms. Waterman's adjustment.

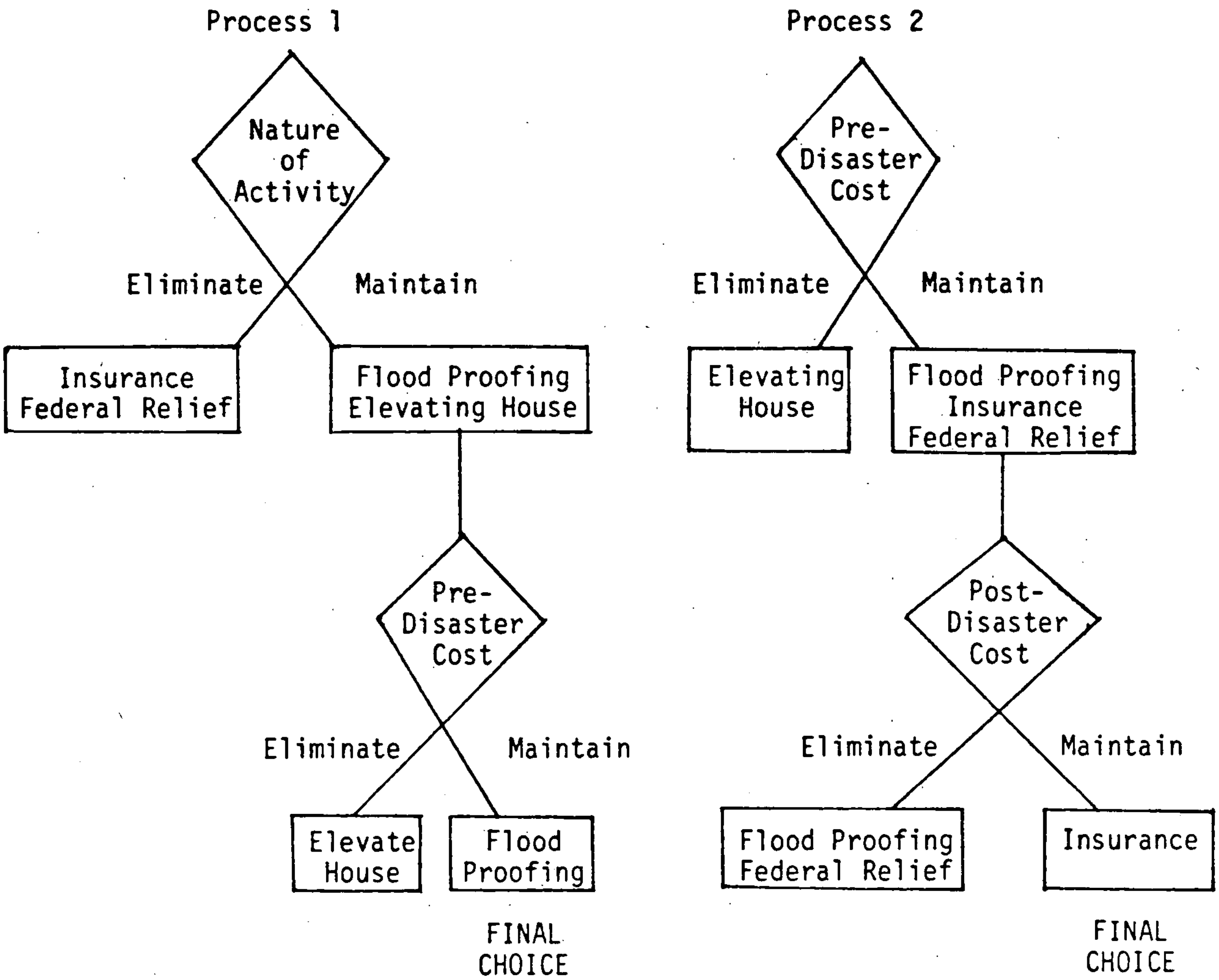

Figure 4. Two processes using elimination by aspects.

Stakeholders / Strategies	Flood Plain Residents & Businesses	Community	General Taxpayers	Private Sector Groups	Government Agencies
A. Flood Proofing					
B. Subsidized Insurance					
C. Land Use Regulations					
D. Flood Control Works					
E.					
Combinations of Different Types of Above Approaches					

Figure 5. Strategy - Stakeholder Matrix