Journal of Environmental Psychology (1985) 5, 55–67

LEVELS OF ENVIRONMENTAL DECISIONS

OLA SVENSON* and BARUCH FISCHHOFF†*
* *Department of Psychology, University of Stockholm, Stockholm, Sweden S–10691 and † Decision Research, 1201 Oak, Eugene, Oregon 97401, U.S.A.*

Abstract

The language of decision theory is used to model the perspectives of two parties in the management of an environmental hazard. These are (a) individuals whose homes are polluted by radon by-products which thereby pose an uncertain health hazard and (b) the public authorities concerned about those individuals' welfare. The analysis provides a way of anticipating ways in which the perceptions and decisions of these parties are intertwined, as well as how they can come into conflict. It also suggests ways in which these difficulties might be ameliorated by altering the respective decision problems. The heuristic value of modeling decision problems in other contexts is discussed, with brief consideration of the substantive issues arising with acid rain and seatbelt usage.

Introduction

Environmental psychology often contributes to the creation of environmental disputes, by documenting the effects of various stressors on people's health and well-being. Investigators have shown how noise interferes with the ability to learn, how workplace pressures diminish the quality of non-working life, and how crowding strains the fabric of interpersonal relations. In some cases, these studies are the original cause of alarm, suggesting effects that people had not even suspected. In other cases, the studies confirm intuitive suspicions, thereby emboldening people to protect themselves, helping them to pick the most consequential issues, and providing ammunition for their struggles.

Environmental psychology can also help to focus and ameliorate disputes. Studies like those described above can have this effect when they demonstrate the existence of effects so incontrovertibly that they cannot be ignored, or their non-existence so convincingly that interest in them flags. Given the weakness of our research methods, relative to the complexity of environmental systems, such strong evidence is seldom forthcoming. As a result, the healing powers of environmental psychology are found more often in attempts to describe the underlying causes of disputes, by characterizing the positions of their participants.

These efforts may take a variety of forms and have a variety of effects. Where fundamentally different ideologies motivate the stances of opposing parties, then descriptions of their world views can help to make their positions more predictable and comprehensible (although not necessarily more credible) (Cotgrove, 1982). Where participants come from different cultures (within the same national society), then a description of the inconsistent ways in which they use terms can improve communications between them (Green, 1982; Slovic *et al.*, 1979). Where the dispute-resolution process (e.g. hearings, referenda) discourages candor and encourages posturing, then a description of the parties' actual beliefs and concerns can clarify what actually motivates them (Fischhoff *et al.*, 1983; Marcus *et al.*, 1984);

0272–4944/85/010055 + 13 $03.00/0

a description of the process itself can show how it reflects the values of those who control it (Kemp *et al.*, 1984). Where experts question laypeople's ability to participate in environmental management, then descriptive studies can clarify how much the latter know, how much they are capable of learning and to what extent their beliefs are clouded by emotion (Fischhoff *et al.*, 1981; Gricar and Baratta, 1983; Vlek and Stallen, 1980). Conversely, studies of experts' judgments can show the definitiveness of the advice that they offer (Fischhoff, 1985; Murphy and Winkler, 1985).

One strength of all these techniques is that they are quite open-ended, in the sense of being able to reveal diverse patterns of behavior. That strength brings a certain weakness, in that investigations are initially unstructured, relying on the creativity and sensitivity of the investigators to discern patterns. A second strength is that they are non-prescriptive, in the sense of offering no opinion as to how disputes should be resolved. Their corresponding weakness is that they offer little help in going from understanding conflicts to resolving them. We offer here a complementary technique that builds on the strengths of these techniques, while offering some opportunity to overcome their weaknesses.

Its premise is that people choose their responses to environmental issues through some sort of decision-making process. That decision could concern a personal action (e.g. whether to wear a seatbelt), a collective action (e.g. how a country should respond to pollutants coming from a neighbor) or the link between personal and collective action (e.g. whether to sign a petition regarding an environmental issue). The key elements of those decisions are the key elements of any decision: a set of alternative courses of action, a set of consequences that might arise from taking those actions and a set of beliefs regarding the likelihood of each consequence arising from each action. If it were possible to capture the decision-making problems that the parties to an environmental dispute saw themselves as facing, then one should have a fairly succinct representation of the things that matter to those individuals.

By contrasting the decision problems of different parties, one should be able to get some insight into the reasons for disputes (or the lack of them). In some cases, this will show the disagreements to be deeper than imagined; in other cases, they will appear more shallow or restricted to issues that can be resolved by scientific research or existing political processes. In any case, the air should be cleared and the debate focussed.

The most convenient language for describing decisions is that of decision theory, which was developed by philosophers to describe how rational decisions should be made, by economists to describe how actual decisions are made (under the assumption that all decisions are made rationally) and by various consultants who help real people achieve the economists' ideal (Abelson, in press; Fischhoff *et al.* 1985; Fishburn, 1982; Slovic *et al.* 1985). The theory provides a highly flexible language, capable of describing almost any deliberative choice among alternatives in terms of well-characterized concepts. That description would be consistent with rational decision making, but would not assume it. Indeed, rationality could be used as a point of departure, with decision theory's language being used to describe behavior as deviations from the ideal, perhaps suggesting ways in which to help people be more rational (Fischhoff and Beyth-Marom, 1983; Ungson and Braunstein, 1982).

As a tool for illuminating environmental disputes, the language of decision theory can be used entirely descriptively. By providing readily compared characterizations of different parties' positions, it allows diagnosis of the precise sources of disagreement. Such a diagnosis alone can have salutary effects. It may, for example, heighten mutual respect by tracing conflicts to terminological differences or legitimate conflicts of interest (rather than, say, to stupidity, arrogance, or venality). It can ensure that attention is paid to those (potentially overlooked) areas in which the combatants do agree (Edwards, 1980; Gardiner and Edwards, 1975). More ambitiously, it can focus discussion on the key issues, whose resolution might allow the parties to agree on what action to take (even though they maintain different beliefs and values on many subsidiary issues). Its structuring of the parties' perspectives should explain their response to existing alternatives and may even prompt the creation of attractive new options (Chen, 1980; Hammond and Adelman, 1976). Finally, use of a common nomenclature should help investigators compare results across studies (seeing, for example, if a particular deviation from optimality frequently afflicts hazard managers or the public relying on them).

Neither the language of decision theory nor the attempt to explain the bases of disputes is particularly novel. The main contribution of the present proposal is the combination of the two and the use of decision theory without a presumption of (or particular interest in) optimality. The approach is demonstrated here in the context of a case study dealing with an environmental issue of increasing interest, the accumulation of radon in homes, which illustrates a recurrent kind of dispute, that arising from a conflict between the decision problem faced by individual citizens looking out for their own best interests and that faced by the hazard managers looking out for society's best interests. The descriptions of these decisions are derived by analysing both the scientific facts of the problem and the ways in which those facts emerge in the lives of the different parties. These parallel analyses are guided by the particulars of this issue and a general understanding of how people and policy makers make decisions under conditions of uncertainty.

The Issue

Radium is a radioactive element which decays into radon, a gas, which decays, in turn, into radon daughters. When inhaled, these increase the risk of lung cancer. Recently, scientists have come to realize the magnitude of radon releases into homes from both the underlying ground (e.g. granitic rock and shale) and common building materials (e.g. bricks composed of light-weight concrete). Because both sources release radon at a roughly constant rate, the amount present at any time (and the attendant risk) depends upon how well the structure is ventilated. As a result, all other things being equal, well-insulated homes are riskier than drafty ones, meaning that prudent residents are penalized for listening to the experts' advice regarding energy conservation. Under plausible assumptions (regarding inhalation speed, exposure time, etc.), an average radon daughter concentration of 40 Becquerels per cubic meter of air (Bq/m^3) in a home produces a risk of approximately 1 additional case of lung cancer per 10,000 persons exposed per year. Because radiation risks in this stage are roughly proportional to exposure, a concentration of 400 Bq/m^3 would produce an expectation of 10 additional cases per 10,000 persons exposed per year (Statens Strålskyddsinstitut, 1982).

Much of Sweden faces the unhappy combination of tightly insulated homes built on granitic bedrock, using radium-rich building materials. Today, some 40,000 of

Sweden's 3,500,000 homes are estimated to have radon levels above 400 Bq/m³. Increasing the exposure from 40 to 400 Bq/m³ increases the lung cancer rate caused by this hazard from 0.6% to 6% for the exposed population. This translates to a 300 day decrease in life expectancy. By contrast, the risk of lung cancer is less than 1% for non-smokers and about 10% for smokers. The population dose would be reduced by 15% if all homes had less than 400 Bq/m³, by 40% if all homes had less than 100 Bq/m³ (Statens Stålskyddsinstitut, 1982).

The authorities' decision problem is to determine what constitutes an acceptable dose level for all homes. The residents' decision problem is deciding what to do when faced with a particular exposure. These problems are represented schematically in the *decision trees* of Figures 1 and 2. Reading from the left, these representations begin with a *decision node* presenting alternative courses of action. These actions lead to *event nodes*, showing events that affect the consequences following from pursuit of these actions. These events may or may not be predictable, leading to decision making under conditions of certainty or uncertainty, respectively. Further decision (and event) nodes may arise, until eventually a set of consequences is considered. At times, such qualitative structuring of a problem provides all the insight that decision theory has to offer (as a guide to either making decisions or describing them). At times, there is further benefit to estimating the model's parameters, namely, the *attractiveness* of the consequences of the various action–event sequences and the *probabilities* of their arising.

The Residents' Decision Problem

Although radon poses a threat to most Swedish homes, it is greatest for those built between 1950 and 1975, when construction relied heavily on lightweight concrete. More modern houses not only use safer materials, but must meet a standard of 70 Bq/m³. Older homes were built with non-radioactive materials (and face only the threat from bedrock radiation). For the sake of simplicity, we will focus on the residents of middle-aged homes and assume that all are owners (which is generally true for single-family homes, but not for apartments).

Insofar as there is no radiation standard for these homes, their occupants' initial decision is whether to consider the problem at all. Figure 1 represents this decision as a choice between the residents having their homes tested and doing nothing. A governmental agency conducts the tests at little cost. The event that follows is the existence of a particular radiation level, which is made explicit for those who take the test and is a matter of guesswork for others. The likelihood of these different levels in a randomly selected house from this population is the same in either case (and is discussed in the context of the authorities' problem). What that risk is perceived to be by testers and non-testers would require empirical study (Lichtenstein *et al.*, 1978; Weinstein, 1980).

Once the time of testing has passed, residents face a second decision. In it, they must choose between leaving their house as is, improving its ventilation, drastically remodeling it (to remove the offending building materials), and leaving it for a new home (with a low radiation level). There seem to be four consequences with major significance for one or more of these action–event–action sequences.

(a) *Radiation health risk*. The risk is low either when the house has little

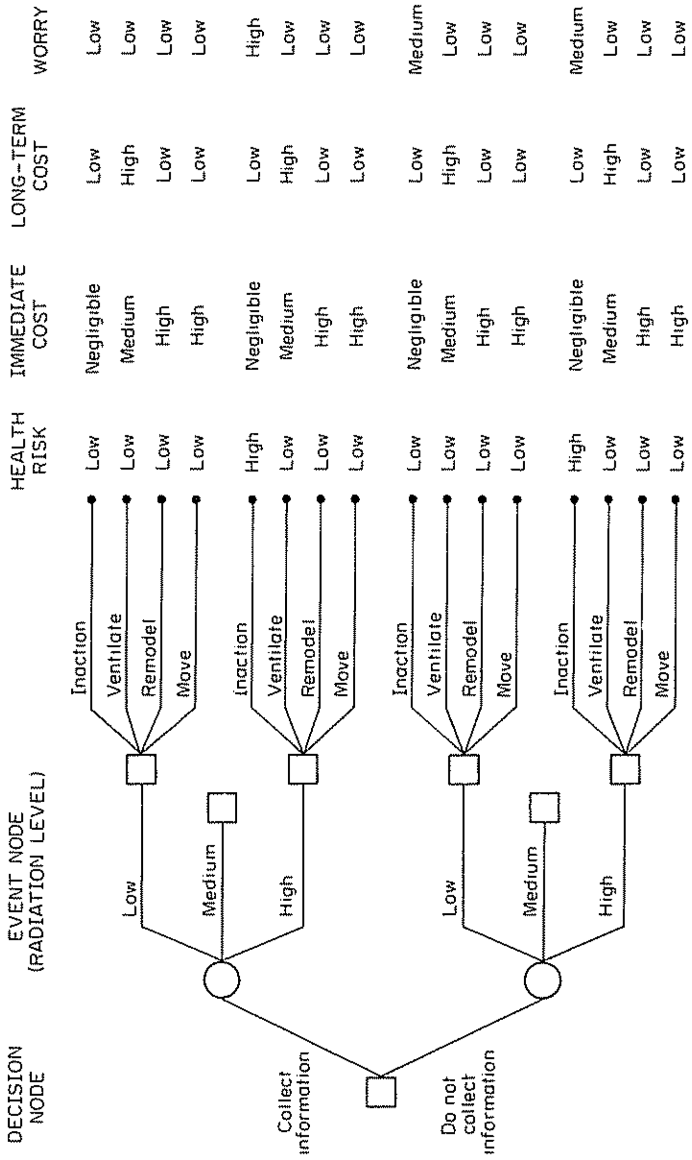

FIGURE 1. The radiation hazard in homes from the residents' perspective.

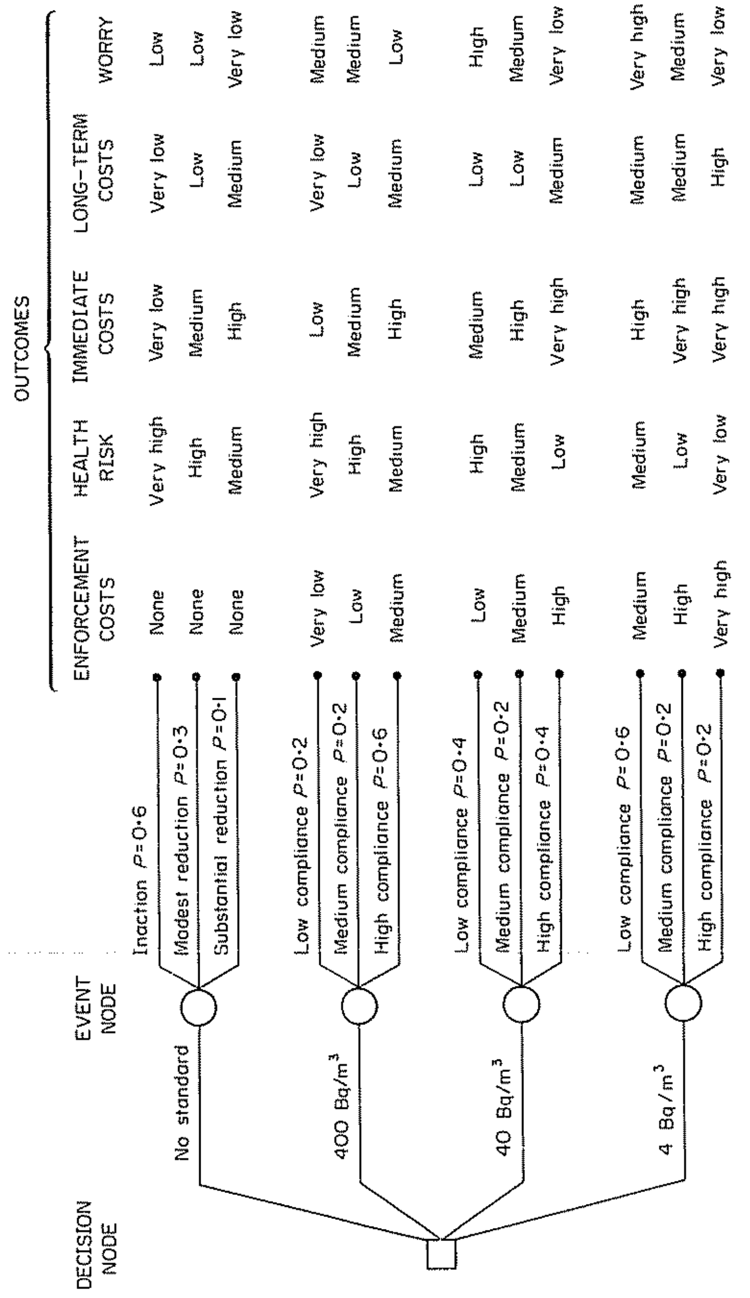

FIGURE 2. The radiation hazard in homes from the authorities perspective.

risk in the first place or when steps are taken to reduce it. It is high only when the resident is inactive in the face of great exposure (known or unknown).

(b) *Immediate monetary costs*. These are negligible with inaction, low with improved ventilation (arising mainly from the need to bolster the heating system), and high with remodeling or moving.

(c) *Long-term costs*. These are substantial only with improved ventilation, due to the cost of heating a deliberately drafty house (Note 1). New and remodeled houses avoid exposure, rather than reducing it.

(d) *Worry*. The risk has received enough publicity in Sweden to make the average resident moderately worried in the absence of information about their specific home (Sjöberg and Jansson, 1982). Worry can be reduced by active steps (of ventilating, remodeling, and moving) or receipt of a low test result. It can be increased by a bad test result, especially when no action is taken.

These evaluations are roughly characterized in the outcome columns of Figure 1. Because all are described negatively, the best possible outcome profile is 'low, low, low, low'. The only way to get that outcome is to do nothing after having been found to have little radiation exposure, making inaction the *dominant* option following a low test result (a conclusion that was obvious without creating a decision tree).

A high test result creates a more complicated situation, necessitating tradeoffs among the consequences. Here, the decision tree proves more useful for clarifying the problem. Inaction leads to high risk and high worry, two aversive consequences that can only be reduced by an active response incurring substantial financial costs. Because the choice among the active responses is purely a matter of economics, the authorities could help residents considerably by providing them with the sort of precise cost estimates that it is difficult (and inefficient) for individuals to produce on their own. If these economic analyses do not point to a preferred action, then it may be useful to enrich the consequence set with factors such as the disruption caused by the options or the regret likely if they do not work as planned. Integrating these factors with the economic factors, and comparing them all with the benefits of reducing the health risk (and its attendant worry), requires evaluative judgments. Although these judgments could legitimately be different for all residents, everyone could be helped by a common set of elicitation techniques designed to help people understand their own values as applied to this issue. Developing such aids to decision making is another service that the authorities could render.

For residents whose houses have tested high, these tradeoffs are difficult but clear cut. By contrast, residents who have avoided testing can only speculate about the risks they face. Any action that they take risks incurring a large expenditure without any assured reduction in risk (but a certain reduction in worry). Although this suggests the advisability for all residents of being tested, the decision tree points to a few exceptions. One arises with the absence of uncertainty; residents who feel that they know their risk even without testing can proceed to the action decision. A second exception arises in the absence of opportunities for uncertainty reduction, as might be perceived by residents who distrusted the scientists and their tests, for whatever reason (Cotgrove, 1982). A third exception arises when residents lack the resources for coping with demonstrated risks. Comparing the respective 'high exposure–inaction' rows with and without testing shows that testing increases worry from medium to high. As a result, the decision to test becomes a choice between a sure thing (the current medium level of worry) and a gamble offering some probability of low, medium and high worry (depending upon the outcome of the test). If it is extremely aversive to know for certain that one is in daily danger but too poor to do anything about it, then it may be quite reasonable to avoid testing.

If this last situation seems unacceptable, then there may be pressure to change the structure of the decision problem. One possibility is to create the new option of having someone other than residents absorb the costs of making their homes acceptably safe. That someone could be the original construction companies (following principles of strict liability) or some branch of government. With this new decision problem, other event nodes and consequences may become pertinent, leading to a redrafting of the decision tree. For example, a key event might be the number of other poor residents who have tested high; if the number is large enough, then they may become an effective lobby for compensation. Indeed, further analysis might show the advisability of refusing the test, so as to help foil the voluntary testing program, so as to force compulsory testing, so as to create a large pool of angry poor residents. Although decision theory cannot create such options, it can prompt the search for them, by showing unacceptable situations in stark relief, and so help to organize thinking about the alternatives.

The Authorities' Decision Problem

As with other environmental decisions, the 'authorities' concerned with radon are found in a number of agencies, subject to the internal and external politics of the allocation of resources within and across institutions. For the sake of simplicity, they are treated here as corporate bodies whose sole criterion when evaluating decision options is the 'public good'. Figure 2 shows a decision tree in which the options considered are alternative standards for acceptable residential exposures. These are: (a) no standard at all, (b) 400 Bq/m^3 (associated with a lifetime cancer risk of 6 in 100), (c) 40 Bq/m^3 (the current standard for exposure in Swedish work environments) and (d) 4 Bq/m^3 (which would make homes 10 times safer than workplaces). Alternative (d) represents a relationship that characterizes the allowable exposures for the public and workers in many other domains—unlike radon, for which homes are currently allowed to be much riskier than workplaces (Derr *et al.*, 1983). The standard for new homes is 70 Bq/m^3, whereas for existing homes there is no firm standard.

The key event determining the consequences of adopting each alternative standard is the degree of public compliance with it. That degree is described here in terms of three representative values: high, medium and low. The probability of achieving each of these rates should depend on both the degree of enforcement and the stringency of the standard (increasing with the former, decreasing with the latter). As a result, higher compliance is associated (in the tree) with higher enforcement costs and lower compliance costs. In so far as one cannot speak of compliance with 'no standard', the event following that action is the level of voluntary action by residents.

The specific probabilities given in Figure 2 are very rough estimates, based on the assumption that residents will do relatively little in the absence of firm action by the authorities (reflecting both the expense of action and the difficulty of knowing what to do). More precise estimates might be derived by detailed analyses extending

Figure 1 to describe the decision problems faced by individual residents. That analysis could rely either on available economic and risk statistics or upon psychological measures of the residents' perceptions (Kunreuther *et al.*, 1978).

At first glance, the consequences of the authorities' actions resemble those of the residents, with the outstanding difference of 'enforcement costs'. These would include both the budget of the regulatory agency and social costs, such as public resentment or confusion within the construction industry. From them, would be subtracted any social benefits of the regulatory process, such as building confidence in government or educating the public about the risks (Fischhoff, 1984).

On closer examination, the similarity of the remaining consequences to their counterparts in Figure 1 proves superficial. One difference is that here the costs and benefits are aggregated across all members of society. Thus, for example, although an individual resident might realize a reduction in risk by leaving a high-radon house, that change would not be counted as a societal gain unless the house stood empty (so that the exposure was not shifted to someone else).

A second difference in the two sets of consequences is their specificity. Although the event nodes specify the proportion of residents taking some action, they do not indicate what those actions will be. In order to proceed, we assume that residents who act are equally likely to move, ventilate, and remodel. Analysing the decisions of individual residents (Figure 1) would be one way of improving on these estimates for Figure 2.

A final difference between the consequence sets is the source of the values that they express. Whereas individual residents have sovereignty over how they weigh the consequences of personal decisions, the authorities are expected to express (and protect) society's values. Thus, for example, although residents may choose ventilation over remodeling because the short-term costs are lower (even though the long-term costs are higher), the authorities should maintain a longer planning horizon when weighing the relative importance of these two consequences. Whereas individual residents' decisions regarding how much to pay for health protection is likely to reflect their personal ability to pay, the authorities should treat all citizens as equally valuable (Note 2).

Assessing the approximate magnitude of the consequences associated with each action–event sequence is relatively straightforward, except for 'worry'. Pending empirical studies of what governs worry in these particular situations (Baum *et al.*, 1983; Elliot and Eisdorfer, 1982), we have assumed that people interpret the stringency of government action as indicating the severity of the radon problem. Therefore, inaction causes the least worry when there is no standard and the most worry when there is a stringent standard. If the costs of worry seem great, then the authorities might hesitate before issuing a standard for which they could not achieve substantial compliance. We have also assumed that compliance with a tight standard eliminates worry, whereas compliance with a weak standard still leaves people uneasy.

Contrasting the Problems

Neither of these decision trees is definitive. In order to derive firm recommendations from them, one would want to flesh them out in various ways, such as assessing the probabilities more precisely, quantifying the consequences, elaborating the event nodes. However, even a sketchy analysis can clarify the structure of a decision problem. In this case, it shows the differences between the options, consequences, and uncertainties of the residents and authorities, even though they are ostensibly grappling with the same problem. It shows how consequences bearing the same name may have different meaning and different evaluations in the two contexts. Diagnosing these differences can improve communication between the groups by prompting a common nomenclature and improve respect between the groups by showing the potential legitimacy of their individual perspectives. In some cases, the result will be to reduce conflict, by showing differences to be more apparent than real; in other cases, conflicts will be shown in greater relief.

The analysis may also reveal ways in which decisions at the two levels are coupled. For example, if the authorities adopt a strictly enforced standard, then the residents have few decisions to make. Conversely, if the residents act spontaneously, then the authorities have no need to act. On the other hand, if the residents feel that they cannot afford to act, then they may pressure the authorities to add compensation to its option set.

More generally, where there is conflict or coupling, there will often be pressure to change, which can lead to changes in the respective decision problems. One side may attempt to impose its will on the other, thereby eliminating options from its decision tree (e.g. prohibiting the issuance of standards). One side may offer side payments to the other, thereby changing the set of consequences (e.g. subsidizing ventilation). One side may attempt to persuade the other to change its beliefs, thereby changing the probability and consequence evaluations (e.g. a public education campaign regarding the risks of radon).

The intent of such actions is to render the actions of the overall system more predictable, by getting the other side to take one particular action. In the short run, though, they serve to render analyses like the present one somewhat indeterminate, in so far as the decisions that people eventually face may be different than the ones described. By highlighting the sources of conflict and the possibilities for resolution, the analysis should prompt people to change the facts of the situation. In this sense, such analyses sow the seeds of their own obsolescence or, rather, the need for iterative analyses, each incorporating the changes prompted by its predecessors. If one side is unhappy with how the other side has altered its situation, then it may exert reciprocal pressures, leading to the need for additional iterations.

A final way in which such parallel analyses can foster change is by showing how sensitive the decisions are to different kinds of information (Raiffa, 1968). For residents, the key information seems to be technical (e.g. how great are the costs? how big is the danger?). For the authorities, it seems to be behavioral (e.g. just how will the public respond to particular standards?). For all parties, the analyses show the importance of information that must come from within themselves, namely how to evaluate the relative importance of the different consequences. If the information is created to meet these needs, then there will be a reduction in the most significant uncertainties surrounding these decisions. Thus, although the decision problems will be changed further, it should be in the direction of a more stable representation.

Extensions

Decision trees can be used to examine the structure of other kinds of environmental disputes as well. Two 'by-products' of the present analyses were descriptions of the individual problems faced by the two parties. Either of these might have been the focus of attention in its own right, with the description of the others' decision being pursued only in so far as it helped with estimating model parameters. Thus, for example, a study of residents' perceptions of random risk might incorporate a side study of the authorities' decision problem as a way of anticipating how their actions might affect the residents' perceptions.

Another use of decision trees would be modeling the position of parties in direct conflict, such as the European nations producing and absorbing acid rain (Svenson and Fischhoff, 1983). Such an analysis might be undertaken (a) by one party to the dispute, in order to get a clearer feeling for how the problem looks 'from the other side' (which might, in turn, suggest compromises that it might offer); (b) by all parties to a dispute in order to clarify and stabilize their own positions prior to negotiations; or (c) by a neutral party hoping to create a comprehensive description of the overall problem which is sensitive to the concerns of all parties.

Whatever kind of dispute is being modeled, the conclusions will depend upon the substantive details of the environmental problem under consideration. For example, automobile seatbelt usage can be viewed from the perspectives of both auto safety authorities and individual drivers. As with the radon example, the authorities' problem is to protect the public interest while being constrained by the public's willingness to act (or to be manipulated). However, unlike the radon example, conflict arises here because the problem is simply not much of an issue for most of the individuals at risk. To the extent that drivers make their seatbelt decisions on a trip-by-trip basis, the risks that they see themselves facing are negligible, making the benefits provided by seatbelts appear small relative to the inconvenience that they cause. These perceived risks are further minimized by the tendency for most drivers to view themselves as being safer than average (Svenson, 1981). By contrast, safety authorities see the overall casualty toll arising from the aggregation of all those seemingly safe trips by seemingly safe drivers. One way to bridge this gap in perceptions is to get individual drivers to adopt something like the broader perspective of safety officials. Although individuals may never care very much about the overall death toll (caused by all those other, unsafe drivers), they may be induced to see the cumulative risk from all of the seemingly safe trips that they take in their lifetime (Slovic *et al.*, 1978). Here, too, modeling decision problems at different levels can suggest ways to change those problems and possibly improve the resolution of environmental risks.

Notes

(1) These heating expenses could be reduced by installing heat exchangers, which clean the air while retaining heat. If the costs of such systems are paid immediately then the balance between immediate and long-term costs shifts from that in Figure 1. If they are amortized over a period of years, then the picture remains the same.

(2) The 'no standard' option would, in effect, return these decisions to the market-place, where one might expect a tendency to let the rich live and the poor die, in so far as the former are more likely to take voluntary action to reduce risk and might do so by selling their radon-contaminated homes to the latter.

Acknowledgements

Support for this research was provided by the Swedish Council for Research in the Humanities and Social Sciences, Swedish Energy Research and Development Commission and the United States National Science Foundation. We thank Kerstin Meyerhoffer, Rocio Klingsell and Leisha Sanders for help in producing the manuscript.

References

Abelson, R. (1985). Decision making. *Handbook of Social Psychology*, 3rd Edit. Reading, Massachusetts: Adison-Wesley.

Baum, A., Gatchell, R. J. and Schaeffer, M. A. (1983). Emotional, behavioral, and physiological effects of chronic stress at Three Mile Island. *Journal of Consulting and Clinical Psychology*, **51**, 565–572.

Chen, K. (1980). *Value-oriented Societal Decision Analysis*. Ann Arbor, Michigan: The University of Michigan.

Cotgrove, S. (1982). *Catastrophe or Cornucopia: The Environment, Politics, and the Future*. New York: Wiley.

Derr, P., Goble, R., Kasperson, R. E. and Kates, R. W. (1983). Responding to the double standard of worker/public protection. *Environment*, **25**, 6–11, 36–36.

Edwards, W. (1980). Reflections on and criticism of a highly political multiattribute utility analysis. In L. Cobb and R. M. Thrall (eds), *Mathematical Frontiers of Behavioral and Policy sciences*. Boulder, Colorado: Westview.

Elliot, G. R. and Eisdorfer, C. (1982). *Stress and Human Health*. New York: Springer.

Fischhoff, B. (1984). Setting standards: A systematic approach to managing public health and safety risks. *Management Science*, **30**, 823–843.

Fischhoff, B. (1985). Judgmental aspects of risk analysis. *Office of Management and Budget Handbook of Risk Analysis*. Washington, D.C.: National Science Foundation.

Fischhoff, B. and Beyth-Marom, R. (1983). Hypothesis evaluation from a Bayesian perspective *Psychological Review*, **83**, 237–265.

Fischhoff, B., Slovic, P. and Lichtenstein, S. (1981). Lay foibles and expert fables in judgments about risk. In T. O'Riordan and R. Turner (eds), *Progress in Environmental Management*, Vol. 3. London: Academic Press.

Fischhoff, B., Slovic, P. and Lichtenstein, S. (1983). The 'public' versus the 'experts': Actual versus perceived disagreements about the risks of nuclear power. In V. Covello, G. Flamm, J. Rodericks and R. Tardiff (eds), *Analysis of Actual vs. Perceived Risk*. New York: Plenum.

Fischhoff, B., Svenson, O. and Slovic, P. (1985). Active response to environmental hazards: Perceptions and decision making. In D. Stokols and I. Altman (eds), *Handbook of Environmental Psychology*. New York: Wiley (in press).

Fishburn, P. (1982) *Foundations of Expected Utility Theory*. Dordrecht, The Netherlands: D. Reidel.

Gardiner, P. and Edwards, W. (1975). Public values: Multiattribute utility measurement for social decision making. In M. F. Kaplan and S. Schwartz (eds), *Human Judgment and Decision Processes*. New York: Academic Press.

Green, C. H. (1982). Risk: Attitudes and beliefs. In D. V. Canter (ed.), *Behaviour in Fires*. Chichester: Wiley.

Gricar, B. G. and Baratta, A. J. (1983). Bridging the information gap at Three Mile Island: Radiation monitoring by citizens. *Journal of Applied Behavioral Science*, **19**, 35–49.

Hammond, K. R. and Adelman, L. (1976). Science, values and human judgment. *Science*, **194**, 389–396.

Kemp, R., O'Riordan, T. and Purdue, M. (1984). Investigation as legitimacy: The maturing of the big public inquiry. *Geoforum*, **15**, 477–488.

Kunreuther, H., Ginsberg, R., Miller, L., Sagi, P., Slovic, P., Borkan, B. and Katz, N. (1978). *Disaster Insurance Protection: Public Policy Lessons*. New York: Wiley.

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

Marcus, A. A., Nadel, M. V. and Merrikin, K. (1984). The applicability of regulatory negotiation to disputes involving the Nuclear Regulatory Commission. *Administrative Law Review*, **36**, 213–238.

Murphy, A. H. and Winkler, R. C. (1985). Probability of precipitation forecasts. *Journal of the American Statistical Society*, in press.

Raiffa, H. (1968). *Decision Analysis*. Reading, Massachusetts: Addison-Wesley.

Sjöberg, L. and Jansson, B. (1982). *Boendes uppfattningar om och reaktioner på eventuell förekomst av strålning från radongas in bostaden*. Department of Psychology, University of Göteborg.

Slovic, P., Fischhoff, B. and Lichtenstein, S. (1978). Accident probabilities and seatbelt usage. *Accident Analysis and Prevention*, **10**, 281–285.

Slovic, P., Fischhoff, B. and Lichtenstein, S. (1979). Rating the risks. *Environment*, **21**, 14–20, 36–39.

Slovic, P., Lichtenstein, S. and Fischhoff, B. (1985). Decision making. In R. C. Atkinson, R. Herrnstein, D. Krantz and P. Suppes (eds), *Stevens' Handbook of Experimental Psychology*, 2nd Edit. New York: Wiley (in press).

Statens Strålskyddsinstitut (1982). *Reviderade synpunter på radongränser inför radonutredningens slutrapport*. Report Number 03/149/82. Stockholm: National Institute of Radiation Protection.

Svenson, O. (1981). Are we all less risky and more skillful than our fellow drivers? *Acta Psychologica*, **47**, 143–148.

Svenson, O. and Fischhoff, B. (1983). *Acid rain: case study of a decision problem*. Report to the Swedish Energy Research and Development Commission. Department of Psychology, University of Stockholm.

Ungson, G. and Braunstein, M. (1982). *Decision making: An interdisciplinary approach*. New York: Kent.

Vlek, C. and Stallen, P.-J. (1980). Rational and personal aspects of risk. *Acta Psychologica*, **45**, 273–300.

Weinstein, N. D. (1980). Unrealistic optimism about future life events. *Journal of Personality and Social Psychology*, **39**, 806–820.

Manuscript received: November 1984
Revised manuscript received: 4 February 1985