“A Conceptual Framework for Managing Low Probability Events”

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Howard Kunreuther

Center for Risk and Decision Processes
Wharton School
University of Pennsylvania
Philadelphia, PA 19104

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I. Intellectual Biography

My initial interest in risk and uncertainty began in September 1964 when I undertook a study at the Institute for Defense Analysis with Douglas Dacy on the economic problems facing Alaska following the Good Friday earthquake of March 1964. We were both surprised to find that behavior did not conform to the patterns prescribed by economic theory. Food prices and rents went down in the short run even though there were shortages in perishable goods and a limited supply of housing. Most residents and business did not have earthquake insurance and hence turned to the federal government for relief and were rewarded with low interest loans and forgiveness grants. It was not unusual to hear many victims remark that financially they were better off after the earthquake than prior to the event due to liberal disaster relief.

Our conclusions from the study were influenced by other studies on behavior following natural disasters[ (White 1953) (Kates 1962) and Fritz and Mathewson (1957)] and discussions with geographers such as Robert Kates and Gilbert White as well as sociologists like Charles Fritz. It is thus not surprising that in summarizing the findings of our study we noted that sociological and psychological factors play an important role in influencing economic behavior and must be explicitly considered in order to develop meaningful and workable policy formulations. (Dacy and Kunreuther 1968).
A look at disaster relief activity following the Alaska earthquake revealed that the generous aid given the Alaskans rapidly became the norm due to an unparalleled series of hurricanes, tornadoes and floods that affected all parts of the country during the next 18 months. If people did not protect themselves prior to a disaster by undertaking mitigation measures and purchasing insurance, then they would turn to the federal government for assistance and Congress would respond.

Government relief reached a peak in the summer of 1972 when Tropical Storm Agnes caused approximately $2 billion in damage to the Northeast portion of the United States. Few homeowners and businesses had flood insurance even though it was highly subsidized by the federal government and was available in some of the stricken areas. As a result, the Small Business Administration provided $5000 forgiveness grants and 1 percent loans to uninsured victims. The total SBA approved loan amounts was $1.2 billion with over $550 million in the form of forgiveness grants. (Kunreuther 1973).

The lack of interest by homeowners in purchasing flood insurance led a group of us to do a study on the factors influencing individuals to protect themselves against low probability-high consequence events. Through field surveys (Kunreuther et. al. 1978) and controlled laboratory experiments (Slovic et. al. 1977) we contrasted two alternative models of choice: the expected utility model which forms the cornerstone of economic analysis and a sequential model of choice which incorporates principles of bounded rationality. (Simon 1955). Our conclusions from this study suggests that individuals have a difficult time dealing with the concept of
probability and tend to rely on salient data (e.g. past experience) and easily accessible sources (e.g. friends and neighbors) rather than utilizing statistical data and making tradeoffs between benefits and costs. These findings suggest that consumers may be the source of market failure when it comes to adopting protective measures prior to a disaster and hence there may be a need for regulatory mechanisms regarding the adoption of cost-effective loss prevention measures or the institutionalization of insurance requirements as a condition for a mortgage, to avoid liberal relief by the government following a catastrophic event.

The need for regulatory measures and the involvement of the public sector became even clearer when my own interests moved from natural to technological disasters. While at the International Institute for Applied Systems Analysis (IIASA) I became involved with a large project on the siting of liquified natural gas (LNG) facilities in four different countries. An international team undertook detailed interviews with key interested parties to determine the process involved in making siting decisions and contrasted the way different countries undertook this process. (Kunreuther, Linnerooth et. al. 1982). Although our studies were descriptive in nature, they raised a number of issues related to the role of compensation, insurance and regulation in facilitating the siting process.

Since returning from IIASA to the University of Pennsylvania I have pursued research related to both natural and technological hazards. A group of us from different disciplines in the social sciences formed a Center for Risk and Decision Processes at the Wharton School in 1984. Its mission is to better
understand the decision making processes regarding low probability high consequence events so as to design more effective policies. As part of Center activities I have been involved in projects related to the siting of the high level radioactive waste repository in Nevada, determining the role of mitigation measures and insurance in dealing with earthquake problems and gaining a better appreciation of how companies cope with catastrophic disasters such as the chemical explosion at the Union Carbide plant in Bhopal, India.

During the past three years a group of Center researchers have been involved in a National Science Foundation sponsored project on "The Role of Insurance, Compensation, Regulation and Protective Behavior in Dealing with Risk and Misfortune". We approach these issues from three perspectives: normative, descriptive and prescriptive. The normative research develops a set of standards, such as efficiency and equity, for evaluating choices under risk, uncertainty and ambiguity. The descriptive work focuses on how consumers, businesses, insurers and government agencies make decisions about what type of protective activities are appropriate for coping with low probability-high consequence events. The prescriptive phase of the project develops risk-management strategies for improving group and individual decision processes and choices.

In reflecting on my approach to problems involving health and safety risks, the work of psychologists such as Baruch Fischhoff, Daniel Kahneman, Paul Slovic and Amos Tversky have greatly influenced my thinking. In particular, I have greatly enjoyed my collaboration with Paul Slovic over many years on problems
involving risk.

Three leaders in their fields have played a key role in much of my research over the past twenty-five years. Kenneth Arrow encouraged me from the outset to question the assumptions upon which the theory of the economics of uncertainty is based, contending that we need to do a better job of modeling the ignorance of the economic agent. Herbert Simon’s pioneering efforts in understanding human behavior and his theory of bounded rationality provided a foundation on which to develop alternative models of choice. Finally, Gilbert White has served as a mentor from the start of my forays into natural disasters through recent work on siting of hazardous facilities. His wisdom with respect to human adjustments to flood and his concern with the importance of institutional arrangements suggested a framework for developing prescriptive analyses. He has been a friend and source of guidance over the years.

II. Introduction

Much of my research on risk has addressed the linkage between descriptive and normative analysis for low probability high consequence (lp-hc) events through prescriptive recommendations. By low probability I am referring to events that are perceived either by the public and/or the experts as having a relatively small chance of occurring to any given individual.

Normative models have been developed by economists and management scientists as guides for good decision-making. In the case of individual behavior, the
expected utility model is the cornerstone for guiding choices between alternatives under risk. It is based on a set of axioms which implies that a rational individual should choose the alternative which maximizes their expected utility. Decision analysis, which utilizes the expected utility analysis, is a normative approach for incorporating probabilities and outcomes so that one can make the right choices under conditions of risk.

In practice, many individuals violate the axioms on which these approaches are based in making decisions either because they take into account other factors (e.g. responsibility, justification) that are not incorporated in the expected utility model or they have a difficult time processing information on uncertainty and consequences.

When one turns to lp-hc events, there are additional problems that we face. Low probability events, by their definition, do not enable individuals to learn easily from the past. At a descriptive level empirical studies reveal that experts often disagree with each other on the potential risks from natural and technological hazards. People often use rules of thumb which either enable them to disregard the possibility of a disastrous event (e.g. "it cannot happen to me") or cause them to exhibit a disproportionate amount of concern regarding other potential hazards (e.g. "I want zero risk"). These heuristics imply that much of the public does not undertake calculations that mirror the computations suggested by normative models of choice. This may be a principal reason why residents in hazard prone areas do not invest in loss reduction measures or purchase insurance even though
their own subjective risk and cost data suggest that they should avail themselves of this protection.

Sound prescriptive analysis should be guided by normative models but modified by the lessons of descriptive behavior. Thus in developing strategies for dealing with lp-hc events it is important to gain an understanding of individuals decision processes within the context of existing institutional arrangements. For example, if one is interested in developing strategies for dealing with natural hazards it is important to know what current programs are currently in effect and how they influence behavior. If the public knows or feels that the government will bail them out of a disaster with forgiveness grants, then it is very rational for them not to purchase insurance. On the other hand, if people do not reflect on what will happen to them should they suffer a severe flood or earthquake loss, then their decision not to protect themselves by purchasing insurance is likely to be based on non-normative decision rules.

Prescriptive strategies involve the use of a combination of different policy tools for managing risks ranging from information provision and market-based incentive systems to compensation, insurance and regulation. In evaluating a particular strategy one needs to consider its impact on resource allocation across all interested parties (the efficiency question) and the differential impact on each of the different interested parties (the equity questions).

Certain programs which may appear to benefit society when looking across all the stakeholders may place an undue hardship on a particular group and therefore
be unacceptable. For example, suppose a large number of disaster victims were forced to go bankrupt following a catastrophic earthquake because they were voluntarily uninsured. This policy might be justified on efficiency grounds by serving as a signal to homeowners and business that they should seriously consider protecting themselves with cost-effective measures in the future. However, our society may not tolerate this callous response to misfortune.

A potential strategy for dealing with this problem would be to determine whether certain protective measures should be required prior to a disaster (e.g. purchasing earthquake insurance as a condition for a mortgage) or after the event (e.g. forcing individuals who get a government loan to buy insurance at the same time)? When is it appropriate to rely on positive incentives (e.g. subsidies) or negative sanctions (e.g. fines) to induce certain actions? What are some of the implementation problems with different strategies? These and other questions addressed in the prescriptive analysis phase can only be evaluated if one has a descriptive understanding of the problem and normative guidelines on which to judge proposed solutions.

The next section of the paper turns to a normative analysis of individual decision making by exploring the expected utility model of choice, the standard approach utilized by economists and policy analysts to guide prescriptive analysis. The limitations of this theory as a descriptive model of choice is presented in Section IV. Section V develops a prescriptive framework for managing risk based on our understanding of human behavior and the types of institutional arrangements
which currently exist. The concluding section outlines future research directions.

III. Normative Analysis: Expected Utility Theory

My particular perspective on risk has its origin in expected utility theory. The demand for insurance illustrates the use of this theory as it applies to consumer behavior. Suppose a person with a utility function $U$ has wealth $W$ and faces a $p$ chance of an economic loss $L$ or can buy full-coverage insurance for a price $I$. Without insurance, the expected utility is

$$p U(W-L) + (1-p) U(W)$$  \hspace{1cm} (1)

With insurance coverage, expected utility is $U(W-I)$. The price $I^*$ at which $U(W-I^*) = p U(W-L) + (1-p) U(W)$ is the certainty equivalent of the risk. Whenever the price of insurance $I < I^*$ an individual should prefer full insurance to remaining unprotected.

A similar analysis can be applied to an insurer who has a utility function $V$ and is considering selling insurance coverage with the objective of maximizing expected utility. Suppose the firm has assets $A$ and is determining what price $I$ to charge for insurance against the loss that the consumer faces. If the firm offers an insurance policy to an individual with the above risk then its expected utility is

$$p V(A+I-L) + (1-p) V(A+I)$$  \hspace{1cm} (2)

If it doesn't offer coverage its expected utility is simply $V(A)$. The premium $I^{**}$ at which $p V(A+I^{**}-L) + (1-p) V(A +I^{**}) = V(A)$ is the minimum premium that a firm would be willing to charge a consumer for full insurance coverage. Market
failure occurs if $I^{**}>I^*$. In other words, the *maximum* price the consumer is willing to pay for coverage is less than the *minimum* price the insurer is willing to charge.

The above analysis can be expanded by introducing other features of a policy such as a deductibles, coinsurance and reinsurance. One can also consider the case of insuring many risks where there is a potential for a catastrophic loss. These variations will change both the indifference values of $I^*$ and $I^{**}$ and hence will determine under what circumstances markets exist and when they fail. Similarly one could incorporate the response of the federal government to an uninsured victim by providing low interest loans or grants. For example, if a person knew that they would receive a grant of up to $5000 if they suffered a disaster loss then the value of $L$ (assuming it was greater than $S$) would be reduced by that amount in equation (1).

In a similar fashion one can utilize expected utility theory to analyze other type problems such as the siting of hazardous facilities in a market setting. Specifically one can determine the *minimum* amount of benefits $B^*$ (perhaps in the form of reduced property taxes) that an individual would require to vote in favor of hosting a potentially hazardous facility where there is a probability $p$ of some accident with consequences denoted by $L$. Those providing these benefits (e.g. the developer, the government) would specify the maximum amount $B^{**}$ they could offer each person. If $B^*<B^{**}$ then the person would favor the facility; otherwise she would not. Such an analysis does not consider the negative social aspects of compensation, such as the person viewing it as a bribe. For these individuals making a tradeoff between
receiving benefits in return for risk will be viewed as inappropriate which would lead them to vote against the facility.

IV Descriptive Aspects of Individual Behavior

Economics is a theory of market behavior and until recently was less interested in individual decision-making by assuming that people utilized normative models of choice such as expected utility theory in determining between alternative courses of action. Cognitive psychology has been concerned with factors influencing human judgment and choice. Recently there has been considerable research on the factors influencing risk perception (Slovic 1987), judgmental biases (Kahneman, Slovic and Tversky 1982) and the alternative decision rules for making choices under uncertainty for low probability events (Weinstein 1987).

Recent studies by psychologists have shown that the expected utility model is an inadequate description of individual choices (Schoemaker 1982; Machina 1987). Some of these will be summarized below. A more complete set of references as they related to lp-hc events can be found in Camerer and Kunreuther (1989).

Biases in Probability Judgments Many people utilize heuristics for estimating probability and these rules yield systematic errors in judgment.¹

The availability bias reflects the tendency for many people to estimate the

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¹ Many of these errors have been documented by the papers in Kahneman, Slovic and Tversky (1982) so will only be briefly summarized here. Additional examples related to natural hazards can be found in Slovic et al. (1974).
probability of an event by the ease with which they can retrieve it from memory. People perceive the likelihood of deaths from highly reported disasters such as fires and homicide to be higher than those of events such as diabetes and breast cancer. The two diseases together actually take twice as many lives as the two more dramatic events. (Combs and Slovic 1974).

Motorists often exhibit an optimism bias by taking the attitude that an accident "can't happen to me". This may explain why Svenson (1981) found in a survey that almost 90% of drivers felt they were better than the median driver. Individuals also ignore low probability events by assuming that it is below a threshold worth worrying about. This may explain the reluctance of residents of flood prone areas to buy flood insurance even when it was subsidized 90 percent by the federal government. (Kunreuther et. al. 1978). With respect to wearing seat belts individuals may be reluctant to buckle up because they perceive the chance of a fatality on any trip to be extraordinarily low. (Slovic and Lichtenstein 1978).

**Importance of Other Attributes**  Some of the violations of expected utility theory are due to attributes other than outcomes. Ambiguity or vagueness about probabilities is an attribute that is ignored in EU but which appears to affect choices people make. (Ellsberg 1961). In the earlier example on insurance, suppose that the probability of loss p is not known exactly, but instead has a distribution f(p) with expected value p*. Under EU, the expected probability p is all that matters.

Yet empirical evidence suggests that ambiguity does matter. In a series of experiments related to insurance, sophisticated subjects (including professional
actuaries and underwriters) indicated a strong aversion to ambiguity for low probability events such as defects on products, earthquakes and leakage of an underground storage tank. When the actuaries were asked to assume the role of an insurer they showed greater aversion to ambiguity than as a manufacturing firm or consumer seeking coverage. (Hogarth and Kunreuther 1989). One reason that the private market has been thin or failed to provide coverage against such risks as environmental pollution, flood disasters and nuclear power plant accidents is that $I^{**} >> I^*$ for many potential firms who would be interested in purchasing insurance. Laypersons judgments of riskiness are based on other dimensions besides probability and losses. Risks that are uncontrollable, unknowable or have catastrophic potential are feared by the public even when they are unlikely. (Fischhoff, Watson and Hope 1984; Slovic 1987). In other words, laypersons are more concerned with risks for which they have little control over, in which there is limited statistical data and where many people could be adversely affected. Experts may be less concerned with these features of a particular risk. By incorporating attributes such as dread or anxiety as part of a multi-attribute utility model, one may be able to explain why the public perceives hazardous waste storage facilities, nuclear power plants or chemical operations as much riskier than do the experts.

One reason why individuals may be reluctant to think about particular risks is because they feel there is little they can do to mitigate the consequences. Few people are testing their homes for radon perhaps because they may not want to know whether they and their children have been exposed to the risk over a long
period of time. They may also be unwilling to incur the personal expense associated with eliminating radon from their home particularly if actions such as opening windows means higher heating bills in the winter. (Smith, Desvousges, Fisher and Reed 1988). Furthermore these remedies must be salient before fear arousals will be effective.

Purchasing insurance may relieve dread in some cases and may be attractive for that reason. For example flight coverage is frequently purchased at the airport) but life insurance is a much better buy. For other risks insurance may remind people of their vulnerability to forces beyond their control. This may partially explain the limited demand for earthquake coverage in California today and flood insurance in high hazard areas of the country.

**Decision Processes** The expected utility model is based on a set of axioms of rational behavior that individuals are assumed to follow. In practice, people often use heuristics where they make tradeoffs between dimensions of alternatives such as probability and utility (Tversky, Sattath and Slovic 1988). The weights placed on these dimensions will vary depending on the type of problem, how it is framed and past experience with the hazard.

In studying individual decision processes for low probability high consequence it useful to distinguish between events where individuals focus on the small chances of their occurrence and other hazards where they attend to the severe impacts of a disaster. For the first class of risks, individuals often treat the hazard as if "it cannot happen to me". In other words if the probability of an event falls below
a critical level then do not take any protective action. The failure of individuals to purchase insurance or adopt mitigation measures against possible disaster losses illustrates this behavior.

For other risks, which experts have estimated probability of occurrence to be extremely low, such as a nuclear power plant accident or leakage from a high level radioactive waste repository, much of the public focuses on the severe consequences of an accident rather than emphasizing the chances of its occurrence. This is one reason why we observe the Not in My Backyard (NIMBY) syndrome for siting those hazardous facilities which the experts perceive to be safe but where the public focuses on the impact of a radioactive leak, an explosion or some other potential disaster.

The weights on the relevant dimensions can also change over time particularly if an accident or disaster has occurred in the interim. For example, the Nuclear Regulatory Commission (NRC) utilized a probability threshold in making its safety design procedures, not concerning themselves with events that were below a critical level. (Fischhoff 1983). The public did not concern itself with this procedure until after TMI. The emphasis since that time has been on worst case scenarios, which is one reason why the development of nuclear power in the U.S. came to a standstill.

Low probability high consequence events are particularly troublesome at a descriptive level for several reasons:

Ambiguity Experts often disagree about the chances and potential
consequences associated with specific events and there is limited scientific data to reconcile these differences. Ambiguities associated with either the chances of an event and/or its consequences influence both consumer and firm decision processes.

**Risk Perception** Even when experts agree, individuals often exhibit perceptions which differ systematically from those of the experts. For example, some events are perceived by individuals as sufficiently low that they are not worth worrying about even though the experts rank the hazard as dangerous (e.g. radon in ones home) while others are considered by the public to be much more likely than the experts estimate them to be (e.g. nuclear power plant accidents).

**Labile Preference** Individuals do not have clear stable preferences with respect to these risks often being unduly influenced by a recent event which may have little to do with the long-term probability. For example, individuals often have an interest in protection following a recent disaster such as a flood or earthquake rather than taking steps to mitigate both the physical and economic losses prior to the event.

VI. Prescriptive Analysis for Managing Low Probability Risks

Each of the descriptive features listed above have implications for prescriptive analysis:

**Ambiguity** If there is considerable ambiguity related to a particular risk then private insurance markets may dry up. Consider the problem of predicting
environmental pollution damage from a hazardous waste storage facility. The large uncertainty associated with the relationship between a person's exposure to a particular chemical should the facility leak and the possibility of he or she contracting cancer makes it difficult to estimate the probability of damage. In addition, new toxic torts, new environmental legislation and court decisions have increased the uncertainty associated with the magnitude of the losses should a suit be filed. Given these characteristics of the risk it is not too surprising that practically all insurance companies have been reluctant to provide environmental impairment liability coverage. What are the appropriate policy tools for dealing with environmental damage and how does that involve the public and private sectors?

Risk Perception If individuals perceive risks differently than the experts, private market mechanisms may not be appropriate ways for dealing with these risks. The failure of individuals to adopt voluntarily protective measures on their personal activities, such as wearing seat belts, raises the question as to what decision processes these individuals are following in making this decision. At a prescriptive level what programs are most appropriate for dealing with this problem? For example, when should regulations such as seat belt laws, be utilized as a way of increasing seat belt usage?

At the other end of the spectrum, it is now well known that communities are strongly opposed to having a technological facility sited in their backyard, even though they recognize that it may benefit society and the scientists and experts
indicate that the risks of such facilities are very low. At a prescriptive level, one can ask what role can market-like solutions such as compensation for risk play in facilitating the siting process? The answer depends on the circumstances under which the public is willing to make tradeoffs between risk and money.

**Labile Preferences** If individuals are greatly influenced by recent events and disregard long-term probabilities then one has the worst of both possible worlds. Failure to mitigate structures and purchase insurance in areas subject to natural disasters makes individuals extremely vulnerable to the forces of nature. Following a disaster there will be enormous pressure by the victims for liberal relief in the form of low-interest loans and grants to help them recover.

To the extent that the government responds with aid, all taxpayers are helping to finance the losses of a few. The problem is exacerbated if the private insurance industry is reluctant to provide coverage to homes and businesses facing the hazard due to the catastrophic loss potential, as was the case 25 years ago with flood insurance and is the case today with earthquake coverage. From a prescriptive vantage point we need to determine whether certain types of regulations (e.g., specific building codes) are appropriate and whether the government should be involved in providing some type of reinsurance protection for catastrophic losses.

Figure 1 depicts a conceptual framework for the development of alternative policy programs. The current institutional arrangements associated with a particular problem affect the relative benefits and costs of different strategies which range from a free market approach at one extreme to regulatory mechanisms at the other. The
relative success of specific programs will also depend on the nature of individual
decision processes and the types of biases that are likely to be present.

The use of alternative policy tools is intimately connected to the ideological
question as to how much government should interfere with individual choice.
Public policies that force people to buy insurance or wear a seat belt infringe on
individual rights. On the other hand, regulations may be more desirable than
current programs such as federal disaster relief or subsidized medical care after a car
accident. In this sense some degree of paternalism by requiring certain actions ex
ante may be viewed as desirable to protect individuals against themselves and spare
others from bearing these costs ex post. (Schelling 1984).

In evaluating the effectiveness of policy tools, societal objectives need to be
considered. These include the impact of the policy tool on overall resource
allocation or social welfare (i.e. efficiency considerations) and the effect of the policy
tool on the distribution of resources across different stakeholders (i.e. equity
considerations).

The approach outlined below is based on the premise that it is most desirable
to let individuals make their own choices through the use of a private market.
However, government action may be required in dealing with low-hc events for
several reasons: imperfection information processing by individuals, need for more
equitable distribution of resources across different parties and negative externalities.
By externalities we mean situations in which the actions of one individual affects
the welfare of others. Taxpayers who cover the costs of an uninsured disaster victim
is an example of a negative externality associated with the failure of a person to purchase insurance prior to a disaster.

To explore these issues further let us consider two societal problems which involve low probability risks and where the behavior of individuals have enormous implications at a societal level: Protection Against Natural Disasters and Siting Hazardous Facilities. In each of these examples private market solutions will be examined first and then I will turn to other approaches. The prescriptive solution for a particular problem may involve a mix of different mechanisms. For example, in promoting auto safety, certain regulations may be desirable (e.g. speed limits) while private auto insurance markets with discounts for cars with passive restraints may encourage purchase of this protective device.

**Protection Against Natural Disasters**

If individuals do not protect themselves against the consequences of natural disasters through the purchase of insurance and/or adoption of loss prevention measures, then the financial consequences from a major disaster are likely to be severe to the potential victim. To the extent that the federal government provides liberal disaster relief in the form of low interest loans and forgiveness grants, the general taxpayer will be partially responsible for financing the costs of recovery. Hence there are private and social costs associated with individuals not adopting protective measures prior to a disaster.

**Free Market** The free market offers one line of attack. However, empirical evidence
on both the demand and supply side indicate that this approach will not work well in practice. Consumers have little interest in voluntarily purchasing flood or earthquake insurance, in part, because they are not fully aware of the costs of insurance and also because they perceive that the disaster will not happen to them. (Kunreuther et. al. 1978). Insurers have been concerned with the catastrophic consequences to them associated with a large-scale flood or earthquake. In the case of floods, no private insurance company has offered coverage since the severe floods of 1927 and 1928 (Manes 1938). Hence the passage of the National Flood Insurance Program of 1968 which offered federally subsidized flood insurance on a nationwide basis with coverage marketed by the private sector.

**Provision of Information** One way to correct for market failure on the consumer side is the provision of information with respect to the hazards as well as protective measures. The availability bias suggests that media publicity, vivid films or visual displays such as plotting flood heights on photographs of familiar buildings (Kates 1962) may help create concern for the hazard. To date, there is no evidence that these approaches have increased the demand for protection.

If individuals only attend to a hazard if they perceive the probability to be above a given threshold, then changing the time dimension may make them more sensitive to the consequences and lead them to adopt protective actions. For example, rather than indicating that the annual probability of a 100 year flood is .01, a homeowner could be told that if she lived in her house for the next 25 years the chances of at least one severe flood would be .22. Experimental evidence with
respect to presenting data on the chances of a fatality from an automobile suggest that motorists are more likely to consider using seat belts when the evidence is presented in terms of a lifetime of driving rather than on a single trip. (Slovic et. al. 1978).

Insurance agents could also provide homeowners with better data on the costs and terms of a policy. If insurers view coverage in terms of an investment they should educate their clients that the best return is no return at all. Otherwise those who purchase policies against low probability events are likely to cancel coverage after a few years of not suffering any losses. Evidence from the flood insurance program reveals that this is likely to occur. (Lave and Lave 1990).

**Economic Incentives**  A more direct approach is to provide some form of economic incentives to encourage individuals to protect themselves against potential losses from a disaster. In the case of flood insurance, the large subsidized rates did not encourage many consumers to purchase coverage. One interpretation of this behavior is that individuals knew that they would receive liberal disaster relief in the wake of a catastrophic disaster. The field surveys in flood and earthquake-prone area revealed that few uninsured homeowners anticipated federal relief following a disaster even if their anticipated losses were greater than $10,000.

As an incentive for homeowners to adopt loss prevention measures, insurance rates could be reduced to reflect the lower risk. The National Flood Insurance program has recently instituted a community rating system whereby insurance premiums for all structures are reduced should specific building codes be
imposed as part of a community-wide mitigation program.

From an efficiency point of view the Federal government could indicate that no disaster assistance would be provided to uninsured victims of natural disasters. Alternatively any uninsured victim who received federal relief would be required to purchase coverage in the future. There is no guarantee that those homeowners required to purchase insurance would maintain their policies for more than a few years, thus leaving them open to future catastrophic losses. From a political standpoint, distributional considerations often dictate legislative actions, so that if many victims of a large-scale disaster were uninsured, special relief measures would be forthcoming.

If information provision and incentives are relatively unsuccessful, one can turn to some form of regulation to force homeowners to adopt protection. In the case of insurance, banks and financial institutions could require flood and earthquake coverage much as they do homeowners insurance as a condition for a mortgage. Today all homeowners in designated flood-prone areas with federally insured mortgages are required to purchase flood insurance but this condition does not generally apply to other mortgages with commercial banks. Specific building codes and land-use regulations could also be imposed on communities.

Siting Hazardous Facilities

The siting of facilities, which are perceived by the public to pose risks to health and safety, has become an especially conflict ridden issue in recent years.
These facilities include solid and hazardous waste treatment plants, land-fills, power plants, sewage treatment facilities and other locally unwanted land uses (LULUs). Opposition to these facilities has been so effective that not a single new hazardous waste and disposal facility has been site in the United States since 1980.

Society faces a dilemma in resolving this conflict. On the one hand, people demand the goods and services whose production yields waste as a by-product. There appears to be widespread agreement that there is a need for properly designed and managed disposal facilities since, in the aggregate their presence would yield benefits in excess of their risks and costs. On the other hand, opposition by citizens is vehement when they learn that their community is being considered for a trash disposal or hazardous waste facility. This results in The Not in My Backyard (NIMBY) phenomena (Popper 1983) which is now part of our American culture. In other words, society may need the facility but don't build it in my community.  

**Free Market** The free market approach to this problem can be simply stated. Those who advocate siting the facility should provide sufficient compensation to those who incur costs from it. If the anticipated benefits exceed the required compensation costs, then the facility should be sited. Otherwise it is not needed.

This approach to the problem has not worked in practice for two principal reasons. People prefer clinging to the status quo even when it may be costly for them to do so. Samuelson and Zeckhauser (1988) provide an illustrative example of a small town in West Germany that was given an offer by the Government to pay for its relocation due to a strip mining project in the area. Despite many options for
redesigning the town, the citizenry opted to maintain its serpentine layout which had evolved without any rhyme or reason over the centuries.

A second reason for the inability of free market approaches to find suitable sites for hazardous facilities is the unwillingness of individuals to trade additional money for increased risk. The findings of a telephone survey of Nevada residents faced with the prospect of hosting a high level radioactive waste facility at Yucca Mountain (approximately 100 miles from Las Vegas) illustrates this point.

Each respondent was asked a pair of willingness to accept (WTA) questions that varied the dollar rebates to be given to residents over a 20 year period should the repository be located at Yucca Mountain. Residents had to decide whether they would vote for or against the repository if they were given a credit or rebate on their Federal income taxes of either $1,000, $3,000 or $5,000 for each of the next 20 years.² If the person voted for the repository, the question was asked again but the credit or rebate was half the original amount; if the person voted against the repository, then the question was asked again and the credit or rebate was double the original amount.

The response to the questions suggest that there was little enthusiasm for compensation even though there were assurances that the facility would meet government safety standards. Approximately 25 percent of the sample was willing to accept the credit or rebate for hosting the facility in their backyard. Even more

²Respondents were randomly assigned to one of the three initial dollar figures of $1,000, $3,000 or $5,000.
surprising to us was residents insensitivity to the amount of compensation. There was no statistical difference in the percentage of Nevadans favoring the facility regardless of whether the initial annual dollar rebate was $1,000, $3,000 or $5,000. (Kunreuther et. al. 1990).

Information Provision  These findings suggest that other prescriptive approaches may be more effective in siting new facilities. With respect to information provision, there is a need to highlight the default option to all those affected by the siting process. The status quo bias creates a false sense of security or well-being with the current situation that often leads to inertia. For example, a presentation of comparative figures on the expenditures associated with shipping waste to a distant location versus the lower disposal costs associated with a new facility in the region are important inputs into any siting debate.

In a similar fashion one can present information on the risks associated with the current methods of disposal in relation to a new facility. To the extent that the health and safety risks associated with modern disposal facilities are lower than the current processes being utilized, an argument on risk grounds alone should provide convincing evidence to adopt the new technology.

Economic Incentives  With respect to economic incentives, there are limitations as to the role that compensation can play in facilitating the siting of facilities. Creative benefit-sharing packages can be developed so that community residents feel that they are better off with the facility than under the status-quo. These benefits may be more appropriate in the form of in-kind compensation such as better health
facilities or improved educational facilities. The advantage of presenting community residents with a package that addresses health and safety needs is that it enables one to demonstrate that the addition of a hazardous waste facility may actually reduce overall risks to the citizenry.

The host community should also be fully compensated for any negative impacts that might occur as a result of the facility. Residents often fear that their property values will fall once a facility is slated for their community and hence they will be hurt economically should they sell their house in the future. Champion International addressed this problem directly before siting a paper sludge landfill in Hamilton, Ohio. They implemented a program to protect owners of property within two miles of the facility from any loss in resale value due to the location of their landfill. The property was priced by two independent appraisers, one chosen by the owner and the other by Champion. Comparable homes in nearby areas that had similar characteristics to Hamilton are used as a barometer for real estate value changes in the absence of the landfill. (N.Y. Times 1990).

Assuming there is a perceived need for the facility some type of competitive bidding procedures between candidate sites might prove useful. One procedure that addresses both equity and efficiency concerns is a lottery-auction mechanism (Kunreuther et. al. 1987; Kunreuther and Portney 1988). In the first stage each of the potential host communities indicate how much they would demand in compensation to host the facility. Call the maximum amount that any community demanded t*. Assuming that t* is considered an acceptable amount by all interested
parties, a lottery is used to determine a candidate site. At the end of this stage, the winner of the lottery is designated as the default host site and $t^*$ would be earmarked for their use if the facility is sited there.

The second stage involves an auction whereby each of the candidate sites (including the lottery winner) has an opportunity to specify the maximum amount it would require to serve as a host community. Each of the communities are aware that they may be required to pay a portion of the final compensation package if they are not chosen as the host site. The developer and other users of the facility may also be required to contribute money to this pool. If no community bids less than $t^*$, then the lottery winner is declared the actual site and would receive $t^*$.

**Regulations** In the case of siting a potentially hazardous facility economic incentives are not likely to be effective if there is concern expressed by community residents on the risks from the facility to present and future generations.

Recent siting experience supports this hypothesis. In the evaluation of a monitored retrievable storage facility in Tennessee, a local task force needed assurance that the facility was safe before even considering its operation, desirability and benefit-sharing package. (Peele and Ellis 1987). Former Governor Bryan of Nevada, in discussing the importance of impeccable scientific studies of the repository as part of the siting process, affirmed the essential role of safety when he stated that "no amount of compensation or federal 'incentives' can ever substitute for safety and technical suitability in the site selection effort." (Bryan 1987).

Guarantees that regulations and stringent safety standards will be met are
critical ingredients to a successful siting process. Several steps can be taken for achieving this objective. Appropriate monitoring and control procedures can be established that are agreeable to both the developer and the host community to ensure that community approved safety standards are maintained. Plans and restrictions for the use of the facility such as those eligible to ship waste can be specified. Finally, and perhaps most important, the community could have the power to shut down the facility temporarily or permanently if the preestablished regulations and standards are not adhered to by the operator.

There is another dimension to the siting process which goes beyond the policy tools outlined above. There is a need for a participatory process that involves all the stakeholders and identifies the nature of the problem and potential solutions. By establishing trust between the various parties by identifying past difficulties and mistakes in siting, allowing for independent assessment of project risks, costs and benefits, and seeking acceptable sites with a voluntary process there is some chance that a host community can be found.

A set of guidelines emerged from a National Workshop on Facility Siting in 1990 which constitute a general approach for allowing the different interested parties in a siting dispute to arrive at a mutually acceptable set of terms for the siting and operation of a facility (National Workshop for Facility Siting 1990). The guidelines represent a set of operational principles and mechanisms which local and regional governments might incorporate into their own approaches. Each siting case requires specialized treatment due to the nature of the affected participants, the project itself
and the political culture.

VII. Conclusions and Future Research Directions

The research on lp-hc events suggests that individuals do not process information in the way that the expected utility model suggests that they do and hence prescriptive analysis needs to take this into account. Future research in this area would benefit from a problem-focused approach which enables one to gain insight into answers to these questions:

(1) What are the characteristics of specific hazards that influence individuals decision processes? Can one link a typology of different hazards to individuals behavior under uncertainty. The different typologies of Hohenemser, Kates and Slovic 1983, von Winterfeldt and Edwards 1984 and Slovic 1987 may provide a convenient starting point for relating the characteristics of hazards to how individuals deal with them.

(2) What different decision processes are utilized by individuals in dealing with different lp-hc events? For some risks individuals focus on the consequences of the event while for others they focus on the low probability. Can one determine when they are likely to utilize one strategy rather than another? Attributes such as justification, accountability to others and responsibility may play a key role in individuals' decision processes. By understanding their importance we may be able to design more meaningful public policies.

(3) How are different prescriptive strategies likely to perform utilizing efficiency
and equity criteria as guidelines? How does one implement specific policies recognizing the importance of current institutional arrangements and how difficult it is to change the status quo?

Laboratory experiments and field surveys provide insight into decision processes. The computerized process technology used by Johnson and Schkade (1989) may help us understand individual decision processes. Experiments on markets and groups choices are useful in determining how policies will work when aggregated across individuals. Research by Camerer (1987) has indicated that the tendency for people to overgeneralize from a small sample of data was not reduced by competition and market forces. It is unclear how policy tools such as incentive systems (e.g. fines and subsidies) and regulations affect individual behavior in a market context when there is uncertainty and information asymmetry.

Finally published data on the success of various policy tools should be examined more carefully. There are many states with seatbelt laws and their relative performance can be compared using variables such as the level of fine and enforcement mechanisms. There are successes and failures in siting potentially hazardous facilities and these experiences should be contrasted. How do variables such as trust, public participation and the nature of the siting process (e.g. voluntary, legislated) play a role in the final outcome?
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Alternative Programs
- Free Market
- Information Provision
- Economic Incentives
- Regulation

Societal Objectives
- Resource Allocation (Efficiency)
- Distribution (Equity)