# FORECASTING THE ADVERSE ECONOMIC EFFECTS

# OF A NUCLEAR WASTE REPOSITORY

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"What is the potential for a high-level nuclear waste repository to have adverse economic effects on the state or region in which it is located?" The answer to this question is obviously important to the candidate sites for such a repository, who need to know what adverse impacts to expect if they are selected. Information about economic impacts may be relevant to the selection decision itself; it is certainly relevant to decisions about compensating the region in which the repository is placed. Although a definitive answer to the question posed cannot be given at this time, there are theoretical reasons to expect economic risks to be substantial and there are studies underway to test these theories. This paper briefly examines these theories and studies.

The Department of Energy is presently seeking to determine which of three sites, Hanford, Washington, Yucca Mountain, Nevada, and Deaf Smith, Texas, is most suitable for becoming the first permanent repository for the nation's high-level nuclear wastes. Much effort has been, and will continue to be, devoted to characterizing the physical and biological risks associated with construction and operation of such a facility. Socioeconomic risks, though less studied, are also quite important. This paper addresses the following question pertaining to social impacts: "What is the potential for a high-level nuclear waste repository to have adverse economic effects on the state or region in which it is located?"

Economic impacts of concern include reduction in short-term visits to the state by vacationers or convention goers, effects on long-term residents (emigration, reduced immigration of retirees), and effects on business (inability to attract new businesses, difficulty in marketing local agricultural products).

The answer to this question is obviously important to the three candidate states who need to know what adverse economic impacts to expect if they are selected for the repository. Indeed, announcement of these three sites as "finalists" and activities over the next few years to characterize the sites geologically, may actually trigger some of these economic impacts in advance of the final decision. Information about economic impacts may be relevant to the selection decision itself. Certainly such information should be relevant to decisions about compensating the region in which the repository is located.

At this time, we cannot give a definitive answer to the question posed. However, there are theoretical reasons to expect economic risks to be substantial and there are methods for testing these theories. This paper will briefly outline some theories and methods that are currently being examined.

## THEORY

Adverse economic impacts may be expected to result from two related social processes. One has to do with perceptions of risk and the reaction to "unfortunate events" associated with the repository (accidents, discovery of radiation releases, evidence of mismanagement, sabotage attempts, etc.). The second has to do with the effects of social stigmatization of the repository and the region in which it is located.

### Perceptions of Risk

Studies of risk perception have examined the judgments people make when they are asked to characterize and evaluate hazardous activities and technologies. One broad strategy for studying perceived risk is to develop a taxonomy for hazards that can be used to understand and predict responses to their risks. The most common approach to this goal has employed the pyschometric paradigm (1,2,3) which produces quantitative representations or "cognitive maps" of risk attitudes and perceptions. Within the psychometric paradigm, people make quantitative judgments about the current and desired riskiness of various hazards. These judgments are then related to judgments of other properties, such as the hazard's status on characteristics that have been hypothesized to account for risk perceptions (e.g., voluntariness, dread, catastrophic potential, controllability). These characteristics of risk tend to be highly correlated with each other, across the domain of hazards. For example, hazards judged to be catastrophic also tend to be seen as uncontrollable and involuntary. Investigation of these relationships by means of factor analysis has shown that the broad domain of risk characteristics can be reduced to a small set of higher-order characteristics or "factors."

The factor space shown in Fig. 1 has been replicated often. Factor 1, labeled "Dread Risk," is defined at its high (right-hand) end by perceived lack of control, dread, catastrophic potential, and fatal consequences. Factor 2, labeled "Unknown Risk," is defined at its high end by hazards perceived as unknown, unobservable, new, and delayed in their manifestation of harm. Nuclear power stands out in this (and many other) studies as uniquely unknown and dreaded, with great potential for catastrophe. Nuclear waste tends to be perceived in a similar way.

Research has shown that lay people's perceptions of risk are closely related to this type of factor space. In particular, the further to the right that a hazard appears, the higher its perceived risk and

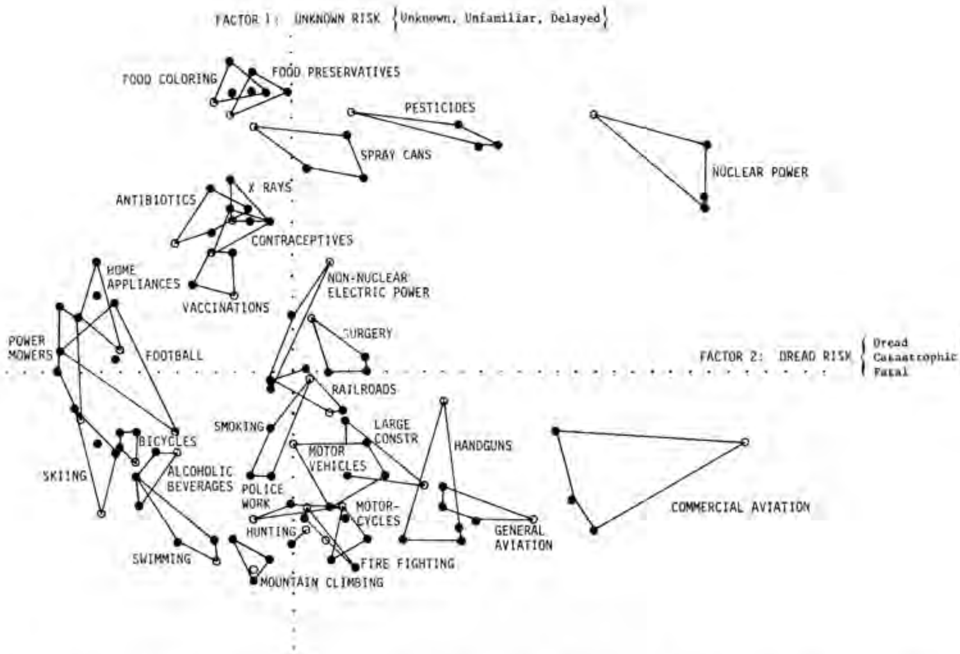


Fig. 1. Location of 30 hazards within the two-factor space obtained from League of Women Voters, student, Active Club, and expert groups. Connected lines join or enclose the loci of four group points for each hazard. Open circles represent data from the expert group. Unattached points represent groups that fall within the triangle created by the other three groups. Source: (9).

the more people want to see strict regulation employed to reduce risk.

## Accidents as Signals

During the construction, operation, and closure of a nuclear waste repository, there will undoubtedly be mishaps or accidents of varying severity. How serious would such mishaps be? The traditional way to answer this question is by performing a risk analysis. Risk analyses typically model the impacts of an unfortunate event (such as an accident, a discovery of pollution, sabotage, product tampering) in terms of direct harm to victims--deaths, injuries, and damages. The impacts of such events, however, sometimes extend far beyond these direct harms, and may include significant indirect costs (both monetary and nonmonetary) to the responsible government agency or private company that far exceed direct costs. In some cases, all companies in an industry are affected, regardless of which company was responsible for the mishap. In extreme cases, the indirect costs of a mishap may extend past industry boundaries, affecting companies, industries, and agencies whose business is minimally related to the initial event. Thus, an unfortunate event can be thought of as analogous to a stone dropped in a pond. The ripples spread outward, encompassing first the directly affected victims, then the responsible company or agency, and, in the extreme, reaching other companies, agencies, and industries.

Some events make only small ripples; others make larger ones which, in the case of nuclear waste, may include economic impacts on the region and state. The challenge is to discover characteristics associated with an event and the way that it is managed that can predict the breadth and seriousness of those impacts. Early theories equated the magnitude of impact to the number of people killed or injured, or to the amount of property damaged. However, the accident at the Three Mile Island (TMI) nuclear reactor in 1979 provides a dramatic demonstration that factors besides injury, death, and property damage impose serious costs. Despite the fact that not a single person died at TMI, and few if any latent cancer fatalities are expected, no other accident in our history has produced such costly societal impacts. The accident at TMI devastated the utility that owned and operated the plant. It also imposed enormous costs on the nuclear industry and on society, through stricter regulation (resulting in increased construction and operation costs), reduced operation of reactors worldwide, greater public opposition to nuclear power, and reliance on more expensive energy sources. It may even have led to a more hostile view of other complex technologies, such as chemical manufacturing and genetic engineering. The point is that traditional economic and risk analyses tend to neglect these higher-order impacts, hence they greatly underestimate the costs associated with certain kinds of events.

Although the TMI accident is extreme, it is by no means unique. Other recent events resulting in enormous higher-order impacts include the chemical manufacturing accident at Bhopal, India, the pollution of Love Canal, New York, and Times Beach, Missouri, the disastrous launch of the space shuttle Challenger, and the meltdown of the nuclear reactor at Chernobyl.

An important concept that has emerged from psychometric research is that the seriousness and higher-order impacts (ripples) of an unfortunate event are determined, in part, by what that event signals or portends (4). The informativeness or signal potential of an event, and thus its potential social impact, appears to be highest for hazards characterized as unknown and catastrophic (as is nuclear waste). An accident that takes many lives may produce relatively little social disturbance (beyond that experienced by the victims' families and friends) if it occurs as part of a familiar and well-understood system (such as a bus crash). However, a small accident in an unfamiliar system (or one perceived as poorly understood), such as a nuclear waste repository or a recombinant DNA laboratory, may have immense social consequences if it is perceived as a harbinger of further and possibly catastrophic mishaps.

In sum, we see that there is evidence that mishaps (large or small) in systems whose risks are perceived as unknown, dread, and catastrophic, can produce impacts far in excess of the direct damages to victims and property. Nuclear waste is a hazard with these perceived qualities that make higher-order economic impacts plausible in the aftermath of an unfortunate event.

### Stigma

Stigma is a concept that originated in the adverse characterization of people and is increasingly being applied to environments. Goffman (5) notes that the word stigma was used by the ancient Greeks to refer to bodily marks or brands that were designed to expose infamy or disgrace--for example, that the bearer was a slave or criminal. As it is used today, the word denotes a victim "marked" as deviant, flawed, limited, spoiled, or generally undesirable in the view of some observer. When the stigmatizing characteristic is observed, perception of the victim changes in a negative way. Prime targets for stigmatization are members of minority groups, the aged, persons afflicted with physical or mental disabilities and deformities, and behavioral deviants such as criminals, drug addicts, homosexuals, and alcoholics. Individuals in these categories have attributes that do not accord with prevailing standards of the normal and the good. They are denigrated and avoided.

Jones et al. (6) attempted to characterize the key dimensions of social stigma. The six dimensions or factors they proposed were as follows:

1. Concealability. Is the condition hidden or obvious? To what extent is its visibility controllable?
2. Course. What pattern of change over time is usually shown by the condition? What is its ultimate outcome?
3. Disruptiveness. Does it block or hamper interaction and communication?
4. Aesthetic qualities. To what extent does the mark make the possessor repellent, ugly, or upsetting?
5. Origin. Under what circumstances did the condition originate? Was anyone responsible for it and what was he or she trying to do?
6. Peril. What kind of danger is posed by the mark and how imminent and serious is it?

Although the sociological and psychological treatment of stigma typically pertains to contexts far removed from that of radioactive waste disposal, it seems evident that stigma can be generalized from persons to environments. Certain environmental features can be repellent, ugly and upsetting (Dimension 3) to the extent that they become visible (Dimension 1). A waste repository is likely to be perceived as disruptive (Dimension 3) and dangerous (Dimension 6).

Stigma resulting from pollution by a toxic substance is described by Edelstein (7), who analyzed a case in which a dairy's cows became contaminated for a short period of time with PCBs. Once this contamination became known (a visible mark) the reputation of the dairy was discredited and its products became undesirable, even though the levels of PCB were never sufficiently high to prohibit sale of the milk. Edelstein shows, step by step, how this incident meets the various criteria of stigmatization put forth by Jones et al.

Although Edelstein's case of stigma involved a consumer product (milk), only a short leap is required to extend the concept to environments that have been contaminated by toxic substances. Times Beach, Missouri and Love Canal, New York come quickly to mind. Other well-known examples are the dioxin contamination at Seveso, Italy, which appears to have produced local economic disruptions in excess of 100 million dollars, and the Amoco-Cadiz oil spill which severely damaged the sea economy and tourist trade of the French Riviera (8).

In sum, it appears that the concept of stigma has meaning in the context of environmental pollution and that a nuclear waste repository may have characteristics that could lead to stigmatization of its host region.

## RESEARCH DIRECTIONS

Research is currently underway to elaborate these concepts of risk perception, accidents as signals, ripple effects, and stigma and to determine their implications for forecasting adverse economic impacts associated with a nuclear waste repository.

Forecasting economic ripple effects requires a more complete theory of impact. The perceived characteristics of hazards that give a mishap high signal value (for example, unknown risk, dread, catastrophic potential) form one element of the theory. However, it is certain that other characteristics, such as evidence of mismanagement, criminal behavior or coverup, neglect of prior warnings, and so on will also trigger higher-order impacts. Further development and validation of the theory will rely on analysis of case histories of unfortunate past events such as manufacturing and construction defects, discoveries of pollution, technologically-caused chronic and acute health hazards, external threats such as sabotage or terrorism, and so on. Psychometric analyses will link the characteristics of these events to their economic impacts.

Potential stigma effects will be studied by means of several approaches--direct and indirect. The direct approach involves various forms of surveys. The simplest involves questions designed to ascertain whether a conventiongoer, vacationer, retiree, or business executive would be dissuaded from going to a city located near a nuclear waste repository or on a major waste transport route.

A more subtle approach is based on a technique that has been used to model the decision proceses of physicians, investment analysts, and admissions officers (9). This method requires people to judge a specific location in terms of its suitability for a convention, retirement home, or new business (separate studies would be conducted for each of these types of judgments). The locations are described in terms of relevant attributes. For example, a possible convention site might be described as

> Easy to reach by plane, low fares
> expensive hotel rooms
> excellent restaurants and entertainment
> moderate climate
> high crime rate
> nuclear waste repository 80 miles away.

The attributes are carefully selected so that, when a moderate number (30 to 50) of cities are judged, statistical methods can disentangle the importance of each attribute in contributing to the judgment of attractiveness as a convention site. The study can thus determine whether presence or absence of a nuclear waste repository influences the judgments and, if so, how strong that influence is relative to the influence of other attributes.

A less direct approach to forecasting stigma effects is patterned after psychometric studies of risk perception. It requires people to evaluate and characterize a large number of LULUs (locally unwanted land uses) and other negative environmental features such as smog, crime, air pollution, prisons, earthquake proneness, chemical manufacturing or chemical waste storage facilities, a nuclear waste repository, a nuclear waste transport route, and so on. Each of the features will be judged in terms of attributes associated with risk, signal value, and stigma. From these judgments, a spatial representation of environmental features will be developed and nuclear waste will be located within that space. Historical data will then be gathered wherever possible on economic impacts associated with the features in the space. To the extent that nuclear waste is perceived more negatively than other features known to have caused serious economic impacts, one can argue by analogy that the impacts associated with nuclear waste may be even more severe.

## CONCLUSION

Although the evidence is not all gathered, it appears likely that perceptions of risk and stigma effects have some potential to produce substantial economic problems for the region in which a high-level nuclear waste repository is located. If studies now underway confirm this view, such economic effects will need to be acknowledged in impact assessment documents and considered in site selection, safety planning, and compensation decisions.

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