Societal Response to Hazards and Major Hazard Events: Comparing Natural and Technological Hazards

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Danger is an inherent part of human existence. On some occasions we court it for the exhilaration of a particular experience. Sometimes this involves human confrontation of nature, as with mountain climbing or white watering; other times it is human confrontation of technology, as with race-car driving or test piloting. Usually, however, it is interaction not confrontation, and the danger is unwanted. Involved are the threatening processes of nature over which we have limited control or the adverse prices of a technology that otherwise adds to our health, wealth, and well-being.

For most of human experience, the events of nature have exacted the highest toll and caused the greatest concern.[1] Throughout history, floods and drought have been the scourge of mankind, registering such tolls as over one million dead in the 1899–1901 drought in India and in the 1931 Hwang-Ho flood in China. The bubonic plague in Europe from 1348 to 1666 is estimated to have killed some 25 million people, roughly one-third of the population of the continent. Influenza during 1917–1919 claimed 13 million victims in India, over 500,000 in North America, and millions in Africa and Europe.

In developing countries, natural hazards remain as major problems. The losses from geophysical hazards (floods, droughts, earthquakes, and tropical cyclones) alone total an annual average of 250,000 deaths and $15 billion in damage and costs of prevention and mitigation,[2] while infectious disease still accounts for 10 to 25 percent of human mortality.[3] But in developed societies, major gains have been made on this broad class of hazards. Geophysical hazards, for example, now result in fewer than 1,000 fatalities per annum in the United States, a figure that pales by comparison with the 40,000 to 50,000 annual fatalities from automobile accidents. Infectious disease, with the notable current exception of acquired immune deficiency syndrome (AIDS), has shrunk to a tiny fraction of its earlier mortality toll. All this has contributed to dramatic increases in life expectancy—from 47 years in 1900 to 74 years in 1979 in the United States.[4] And technology has often been the handmaiden in reducing ancient hazards and extending the life span.

Yet, technology has emerged as the major source of hazard for modern society. The accumulated exposure of 8 to 11 million workers to asbestos since the beginning of World War II is expected to result in as many as 67,000 workers dying prematurely each year over the next two decades, with cancer rates among the heavily exposed rising to 35 to 44 percent.[5] The chemical revolution of the 20th century has produced widespread ex-

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posure of workers and publics to a number of known carcinogens and a larger number whose toxicity remains unassessed. One recent estimate places the burden of technological hazards at 20 to 30 percent of all male deaths and 10 to 20 percent of all female deaths, with overall expenditures and losses at 10 to 15 percent of gross national product.[6]

The hazards of technology pose different managerial problems than those arising from nature. Natural hazards are familiar and substantial accumulated trial-and-error responses exist to guide management; technological hazards are often unfamiliar and lack precedents in efforts at control. Natural hazards tend to have relatively well-understood "hazard chains" (see later), making opportunities for control intervention relatively clear; the hazard chains for technological hazards, by comparison, are often poorly understood, particularly when the consequences are chronic and the sources of exposure multiple. Natural hazards tend to provide only limited potential for preventing events, and, thus, management tends to occur "late" in the hazard chain. Moreover, technological hazards show a wide variation in loci for conrol intervention.

Members of the public tend to see natural hazards as acts of God whose effects can only be mitigated; technological hazards, especially those associated with new technologies or those that are imposed, are assumed to be amenable to "fixes" of various kinds, and amenable to substantial reduction. Managing technological hazards requires the simultaneous goals of enlarging social benefits and reducing risks and, where those at benefit and those at risk diverge, action to reduce inequity. Managing natural hazards requires judging the proper allocation of societal effort and the appropriate types of intervention to be undertaken in risk reduction.

This article inquires into the range of problems encountered by society as it attempts to avoid, and respond to the hazardous events rooted in technology. Two tasks in particular are recognized: first, to characterize the hazard management process and to highlight the particularly difficult problems encountered, and, second, to assess how the major hazardous events arising from technology affect people, their communities, and their institutions.

Hazard Evolution

Hazards may be broadly defined as threats to humans and what they value—life, well-being, material goods, and environment.[7] *Risk,* as differentiated from hazard, may be thought of as the probability that a particular technology or activity (automobile driving) will lead to a specified consequence (death from crashes) over time or activity unit (one driving year). Traditionally, research on natural hazards has envisioned hazards as comprising events → consequences, suggesting three broad classes of hazard management—preventing events, preventing consequences, and mitigating consequences after they have occurred.[8]

More recently researchers have developed a more complex hazard "chain" or model, based upon hazard evolution.[9] This model elaborates the events → consequences chain into a multistage structure (Figure 1). The model begins with an "upstream" component of the hazard in which basic human needs (e.g., food, shelter, security) are converted into human wants. Still in the upstream portion of the hazard chain is the choice of technology, involving considerations of realizing benefits and minimizing risks. Thus, in Figure 2 the need for food results in human objectives to reduce crop damage due to insects through the use of insecticides which represents only one technological option. Inevitably, initiating events (e.g., failure of brakes) trigger a release of materials or energy (e.g., collision). The "downstream" portion of the hazard chain consists of the exposure of humans and ecosystems to these releases, leading to adverse consequences.

Even this elaborated model is a very simplified structure of hazard, for feedback occurs among the stages. Yet, the model is useful in that it provides a standardized means for structuring hazards and for identifying systematic opportunities for hazard control. Each stage in the hazard evolution is connected by links, each of which represents an opportunity for blocking the hazard. Figure 2 provides an illustration of how the hazard chain may be used for identifying a set of managerial control (blocking) opportunities for pesticide hazards. Not shown is a parallel benefit chain that also results from the choice of technology.

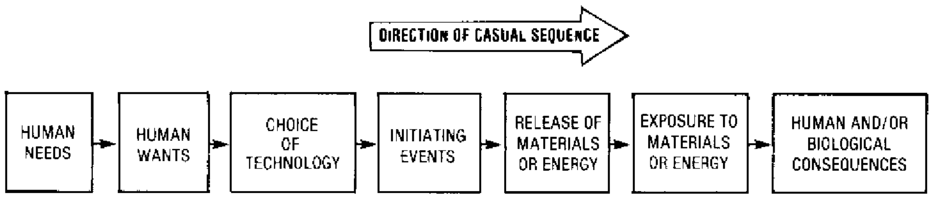
Using this notion of a hazard chain, we next characterize the management process.

A Flow Chart of Hazard Management[10]

Hazard management is the purposeful activity by which society informs itself about hazards, decides what to do about them, and implements measures to control them or to mitigate their consequences. This activity has two essential functions: intelligence and control. Intelligence provides the information needed to determine whether a problem exists, to define choices, and (retrospectively) to determine whether success has been achieved. The control function consists of the design and implementation of measures aimed at preventing, reducing, or redistributing the hazard, and/or mitigating its consequences.

Figure 3 depicts the management process as a loop of activity. In the center of the diagram is the hazard chain through which the deployment of technology may cause harmful consequences for human beings and their communities. We inquire at length into the nature of these impacts later in this article. Four major managerial activities—hazard assessment, control analysis, control strategy, and implementation and evaluation—surround the chain. Each, as we shall see, characteristically involves both normative and scientific judgments. The depicted sequence, of course, is an idealization and simplification of a process that is often not linear or which jumps over stages. It is not unusual, for example, for

FIGURE 1
The Chain of Hazard Evolution as Applied to Technological Hazards



control actions to be instituted prior to a thorough hazard assessment.

Hazard Assessment. This process involves four major steps—hazard identification, assignment of priorities, risk estimation, and social evaluation. A variety of methods—research, engineering analysis, screening and monitoring, and diagnosis—exist for identifying hazards. The scientific capability for these methods has improved enormously over the past several decades. That progress is Janus-faced, however, for it threatens to overwhelm the more limited societal capability to act upon the vast new stores of information and to proliferate low-level hazards.

Somehow these large new hazard domains must be ordered and priorities established for the many competing candidates for managerial attention. And the problem is formidable. The Consumer Product Safety Commission, for example, oversees a hazard domain that includes some 2.5 million firms, more than 10,000 products, and some 30,000 consumer deaths and 20 million consumer injuries. The Toxic Substances Control Act mandates that the Environmental Protection Agency (EPA) screen the 70,000 or more chemical substances in commerce and the thousand or so entering the market each year. The task is not made easier by the fact that establishing priorities receives precious little congressional guidance, yet is laden with value considerations: Is the aggregate risk or the distribution of the risk more important? Should ecological risk receive lower priority than human health risks? Should children enjoy higher priority than adults? How should effects in future generations be valued?

Once a hazard is identified and priority assigned, it is necessary to (a) characterize and, where possible, quantify the stages and linkages in the hazard chain, and (b) evaluate this characterization in social terms. These tasks are often viewed as separate and distinct. Public officials look to scientific experts for advice and evidence on the former while searching their consciences or deferring to the political process for guidance on the latter. Complicating this portion of the assessment process is the fact, addressed at length later in this article, that no simple relationship exists between scientific estimates of risk and public response to it. A great deal of confusion and social conflict in hazard management arises from this departure.

Control Analysis. Following the hazard assessment, control analysis judges the tolerability of the risk and rationalizes the effort that is made in preventing, reducing, and mitigating a hazard. The first of these—judg-

FIGURE 2
Expansion of the Model of Hazard Evolution into the Full Range of Stages Extending from Human Needs to Consequences

The case involves the use of pesticides to suppress crop damage "Downstream" management options involving events and consequences are not very promising or even possible, and "upstream" options involving human wants and choice of technology are most likely to succeed

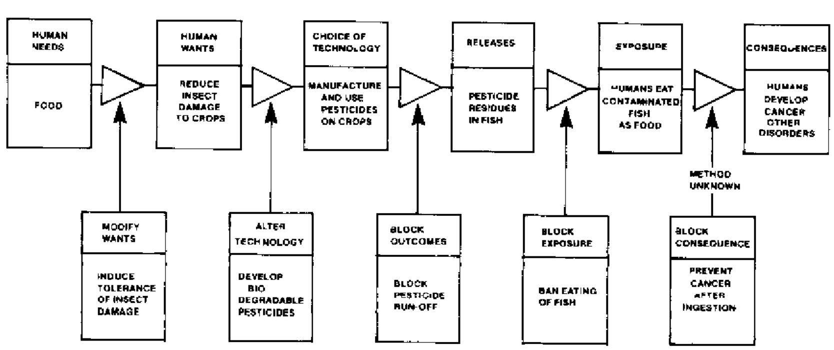
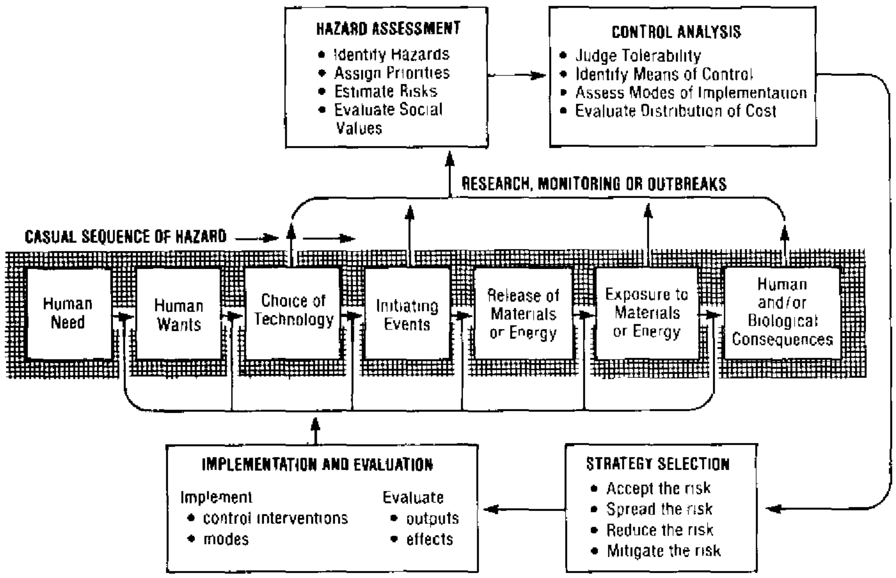


FIGURE 3
A Flow Chart of Hazard Management



ing the tolerability of the hazard—is one of the most perplexing issues in hazard management.[11] Fischhoff *et al.* distinguish four principal methods for judging the tolerability of hazards: risk/benefit analysis, revealed preferences, expressed preferences, and natural standards.[12] According to these methods, a technology is judged tolerable if, respectively, its benefits outweigh its risks; its risks do not exceed those of historically tolerated technologies of equivalent benefit; people's expressed opinions indicate that the risks are tolerable; or the risks do not exceed those fixed by nature through the process of evolution. These methods, it should be noted, are often in conflict and no consensus exists to indicate which are preferred in alternative hazard situations.

Whatever the methods, four different criteria tend to be employed in reaching risk tolerability judgments. According to the first, risk aversion, any level of risk is considered intolerable because of the nature of the product, its use, or its consequences. Thus, we ban biological weapons, DDT, and chlorofluorocarbon aerosols. The other three criteria all involve some form of comparison. Thus, risks may be compared with other risks, often with the assumption that they should be balanced. A well-known, and often criticized, set of risk comparisons is the *Reactor Safety Study.*[13] Another criterion, cost effectiveness, compares the efficiency involved in various opportunities for risk reduction. Controls for forestalling a fatality in automobile accidents, for example, range in cost from $500 for enforcing mandatory seat belt usage to $7.6 million for road alignment and gradient change. Finally, risk/benefit comparison seeks to balance the benefits of an activity or technology against the risk to determine how much risk reduction should be undertaken. The quality of such analyses, as with cost-benefit analysis, depends upon such factors as the messiness of the problem, the skill of the analyst, the way in which the analytic question is posed, the existence of appropriate techniques, and the analyst's ability to fashion new ones.[14]

The second task in a control analysis is to identify the means of control. Here a scientific analysis of the hazard chain is essential in identifying opportunities, ranging rom altering our wants and choice of technology (upstream), to preventing or mitigating consequences (downstream) for blocking the evolution of the hazard. Generalizing from the hazard chain, some seven major control interventions are possible: (1) modify wants; (2) choose alternative technology; (3) prevent initiating events; (4) prevent releases; (5) restrict exposure; (6) block consequences; and (7) mitigate consequences. Complex cases may require a full fault- or event-tree analysis, as in the *Reactor Safety Study.*

Each control action can be realized through different modes of implementation, which may be grouped into three major classes: (1) society can mandate the action by law, regulation, or court order and, thereby, ban or regulate the product; (2) managers can encourage the action through persuasion, incentives, or penalties, and (3) managers can inform those creating or bearing the risk and allow them voluntarily to reduce or tolerate the hazard. Table 1 povides subclasses for each of these major modes.

Finally, there must, of course, be a cost analysis of various control options. Known as cost-effectiveness analysis, this approach permits the hazard manager to select the most efficient action from the available candidates. It is known that existing control measures reflect

TABLE 1
Modes of Implementation

MANDATE	
	Ban the product or process
	Regulate the product or process (e g., performance and design standards, use and dissemination restrictions)
ENCOURAGE	
	Seek voluntary compliance
	Provide incentives (e.g., credits or subsidies)
	Penalize through indemnifying those harmed
	• via the market (wages)
	• via the courts (award damages)
	• via transfer payments (taxes)
	Provide insurance
INFORM	
	Inform hazard makers (by monitoring and screening)
	Inform those at risk (e g., by labeling and advertising)

very different requirements to invest in "life-saving." Wilson, for example, has estimated that the United States in 1975 expended $1,000 for avoiding a death in the liquefied natural gas industry as compared with $750,000 for nuclear power.[15]

Selecting a Management Strategy. Equipped with a hazard assessment and a control analysis, the manager is positioned to select a hazard management strategy. Such a strategy is posited to consist of an overall management goal and a "package" of control measures designed to achieve the goal. The control package will specifically include both control interventions (oriented toward intervention in the hazard chain) and modes of implementation (oriented toward institutional means of control). The management goal will be of four major possibilities (Figure 3).

1. Risk acceptance seeks to achieve voluntary willingness to tolerate risk, usually through risk compensation or increased information. The former is common in occupational settings where workers are compensated, albeit only partially, for risky work by higher wages or workmen's compensation. Similarly, financial incentives may be offered to communities to accept a nuclear power plant or a hazardous waste facility. In other cases, such as the warning labels on cigarette packages or the patient package inserts for oral contraceptives, information on risk enables those exposed to do their own weighing of benefits against risks.

2. Risk spreading seeks to make a risk distribution more equitable by redistributing it over social groups, geographic regions, or generations. The new distribution may aim at equalizing the risk or, alternatively, allocating risk in relation to benefits or to a differential ability to bear the risk. A notable example was the introduction of tall stacks in coal-burning plants to reduce local pollution, resulting in long-distance transport of pollutants and a new regional inequity in risk.

3. Risk reduction has already been discussed at length. Suffice it to note here that efforts to reduce risk often involve the curtailment of benefits or the creation of new, and sometimes unsuspected, hazards. A classic example from the early 1970s was the introduction of the flame retardant TRIS into children's pajamas and the subsequent discovery that TRIS is a carcinogen.

4. Risk mitigation does not attempt to prevent consequences but rather to mitigate their effects once they have occurred. Typical actions include disaster relief, medical intervention, and family assistance. A number of these will be discussed later in this paper when we address the impacts of technological disasters.

Although presented here as a rational choice process, hazard management strategies tend to develop in piecemeal fashion, are a result of trial and error, and build upon previous precedents. They also result, of course, from the mutual partisan adjustments of which Lindblom writes.[16] However they develop, they nearly always must steer a course between the realization of the benefits of a technology and a minimization of its risks. When the hazard chain is poorly understood scientifically or when the control analysis is incomplete or highly uncertain, society tends to respond by mitigating consequences. A prominent example is occupationally induced cancer, where exposure sources are multiple and the causal agents largely unknown. By contrast, a "mature" hazard management strategy will tend to employ a complex system of interventions along the hazard chain and a rich set of modes of implementation. Such a system evolves both from growing scientific knowledge and from trial and error in attempts at control.

Implementation and Evaluation. Implementation is a crucial and problem-prone stage of hazard management. A lengthy review by the National Research Council (1977) of the Environmental Protection Agency indicates why control actions often fail in implementation:[17]

- Administrative resources are often inadequate, particularly in a decentralized system in which lower administrative levels face large enforcement burdens but lack resources.
- Those charged with implementing health and safety control actions are often reluctant to do so, because it conflicts with other organizational and political interests.
- Implementation always contains implicit notions as to how hazard managers can be induced to accept mandated control actions. If these assumptions are incorrect (and they often are), implementation fails.
- Where managers lack monitoring and surveillance resources in their intelligence function, implementation becomes dependent upon data furnished by hazard makers.

Many of these problems have pervaded the Occupational Safety and Health Administration (OSHA). Even before extensive cutbacks during the Reagan administration, OSHA had very limited inspection and enforcement programs. Only about 10 percent of OSHA inspections of places dealt with health issues, yet safety hazards, the easiest violations to identify, were often trivial in their overall impact on health and safety. Meanwhile, the average fine for most violations was a few dollars and even the small number of serious violations carried penalties of several hundred dollars.[18] Compliance, in short, was heavily dependent upon the voluntary cooperation of the regulated firms, a situation which has increased and has been formalized in recent years.

Hazard management is not complete, even with the implementation of control measures. There must be some evaluation of the accomplishments of hazard management, an assessment of the broad consequences of managerial outputs (i.e., control measures). This evaluation involves the application of social criteria to determine whether success has been achieved. Four criteria may be proposed for such retrospective assessment. First, the managerial actions must be effective: the degree of risk reduction, redistribution, or acceptance actually achieved must be measured. Second, management must be efficient: the two relevant measures of efficiency are minimal interference with technological benefits and the choice of the most cost-effective measures for risk control. Third, management must be timely: managers should move through assessment and control activities with a minimum of delay. Finally, management should be equitable: risks and costs to those not benefiting from the technology should be minimized.

This flow chart of hazard management identifies major activities which must be undertaken and issues which will arise. No matter how competent the management process, hazardous events will still occur, harm people, disrupt communities, and endanger institutions. We turn next to such occurrences, their effects, and potential means of response.

Major Hazard Events: Impacts and Social Response

Several conceptual frameworks exist for assessing public response to technological hazards and emergencies.[19] In comparing the response to the threat of a flood with behavior during a derailment that posed risk of release of radioactive material, Perry noted that every disaster situation has the same phases of social response —threat detection, threat evaluation, and information dissemination.[20] Thus, although characteristics of disaster agents may vary, natural and technological disasters may be examined within the same conceptual and analytical framework. Nevertheless, differences in characteristics of threat between natural and technological hazards do result in different management problems (noted above) as well as different patterns of response.[21] These contrasts are important to understand in order to develop effective means to control and manage the hazards of technological origin. This section of the paper highlights some of these differences by focusing on: (1) emergency events resulting from failures in technology, and (2) sociopsychological impacts of recovery from technological disasters.

It is important to distinguish among three generic types of technological hazard events—mostly releases in terms of the hazard chain. The first, the ubiquitous (or routine) hazard events of technology, involves exposure over a substantial period of time to low emissions of chemical contamination or other hazardous activity that poses chronic and, perhaps, unacceptable consequences. These hazards do not represent major failures and are typically addressed by established management structures and processes. The second class of hazard event involves the failure of a technology, resulting in release or potential release of hazardous material and necessitating emergency response. The third group, technological disasters, is characterized by exposure to harmful substances for a particular population and locale, resulting in major loss of life or injury with long latency periods, social disruption, and relocation. The Love Canal and Times Beach situations represent this class. In such events, the hazards are often identified through scientific efforts and formal risk assessments. Emergency responses to disasters are less important than interrupting the causal chain of the hazard and thereby averting adverse consequences. The failure of a technology may result in disaster if loss or impact is substantial. The distinction between the two latter classes of hazard events is based on the greater likelihood of occurrence of small random events that can usually be contained or mitigated through emergency responses. If technological failure results in adverse and long-term secondary effects with attendant social disruption, then it can be defined as a disaster.

The first class of hazard events, routine releases of hazardous technology, has been discussed above in the context of the flow chart of hazard management. We turn, therefore, to the two classes of hazard events that represent major failures and releases.

Failure of Technology Requiring Emergency Response. This class of hazard events includes accidents at nuclear facilities, transportation incidents with potential release of hazardous substances, and explosions at fixed facilities posing both immediate and chronic threats to health. Growing public concern over this class of hazard events may reflect its increasing incidence. Figures 4 and 5 provide time series data on the incidence and magnitude of damages from hazardous materials transit accidents. As Figure 4 indicates, the percent of rail hazardous material accidents to the total number of rail accidents has increased from less than 8 percent to 11 percent over the 1976 to 1982 period. This is significant because 35 percent of all freight trains have been estimated to carry hazardous material. Highway accidents involving hazardous material have remained fairly steady, between 5 and 6 percent of all commercial highway accidents. In addition, as Figure 5 shows, property damages per accident for hazardous material carriers are also increasing and are severe when compared to damages of non-hazardous material carriers. A recent survey of 300 community and organization officials in

19 cities found a very high level of perception associated with the probability of a chemical accident. Although local emergency organizations assigned even higher probabilities to the occurrence of such accidents, communities were generally found to be inadequately prepared for serious chemical emergencies.[22]

Community vulnerability to chemical threats is a function of the magnitude and nature of the risks and level of preparedness. With natural hazards, communities are generally familiar with the threat, have past experience, and may have previously instituted controls to prevent or reduce damage. Floods, for example, can be forecast, and rise in water level can be monitored as a basis for an evacuation warning. In coping with natural hazards, individuals and communities enjoy control of the situation in terms of the adjustment choice; experience and familiarity with the hazard are critical decision factors in response, and protection measures are understood.

By contrast, familiarity with the hazard is relatively low in communities suddenly faced with technological emergencies.[23] First, the random nature of occurrences of serious chemical releases means that few communities have experienced these hazards. Thus, predictive knowledge is low and effects of release may be unknown in small communities. Even where such experience has occurred, serious problems exist in the effectiveness of response and emergency management, particularly with respect to threat identification and coordination of response. Quarantelli has suggested that first on-scene responders typically lack knowledge of the full range of possible responses to the variety of chemical hazards and that the identification of chemical hazards during emergencies has often been a problem.[24] Problems in hazard identification, lack of experience with chemical emergencies, and fear of secondary impacts has resulted in both overresponse and delays in emergency management. Small communities also tend to rely on outside resources for aid in response to serious chemical incidents. Such vertical dependencies for response at the local level have resulted in low levels of community preparedness to chemical hazards.[25] Such dependencies are also not free of problems. In Arizona the state supports six hazardous material response teams whose responsibility it is to coordinate emergency response to local communities. However, an ongoing assessment of the role of these teams suggests that: (1) Their dispersed locations have resulted in arrival at the scene of an emergency only after initial actions were taken by local response organizations; and (2) they have not prevented conflict between local and state emergency planning organizations.

Prevention of such hazard events is very difficult. Rerouting of hazardous cargo is possible, but this implies knowledge, which may be lacking, of the type and volume of material and the jurisdictional authority of communities to take action. Prevention consists of activities and decisions that reduce the probability of occurrence of technological failure. Most of these activities occur at the national level through promulgation of engineering containment standards, packaging standards, and enforcement of regulations, such as those of the Department of Transportation under the Hazardous Materials Act. Hazard prevention is less efficacious at the local level. At the community level, actions to reduce risk through various activities—zoning, screening of hazardous industries, disclosure of materials stored or processed by firms, and inspections by fire organizations—are contingent on community norms and values regarding the relationship of roles between private and public sectors.

Unlike most natural disasters, technological failures can occur quickly and without warning. Perry found that quick onset of technological accidents places an enormous burden, particularly for evacuation decision making, on emergency managers.[27] He argues that in contrast to natural disasters, technological emergencies are compressed in time; that is, the time between hazard awareness, problem identification, risk assessment, and the decision to evacuate may be extremely short. Chemical release into the environment may also be hidden and identified only after considerable lapse of time. Thus, unlike natural hazards, technological hazards may not be readily observable and may require a specialized analytical capability, lacking in most communities, for identifying, estimating, and evaluating the risk. Lack of familiarity with technological hazards, generally low levels of community awareness and preparedness, the rapid onset of the hazard event, and the potential for larger secondary consequences present critical problems for emergency managers.

Lack of familiarity with technological hazards and the perception of these hazards are important factors in differentiating response to technological and natural disasters. Although no formal evacuation order was given at Three Mile Island, approximately 40 percent of the population within 15 miles of the disabled plant evacuated.[28] The extent and volunteer nature of the evacuation contrasts with the general reluctance in natural disasters to evacuate until the event is perceived as extreme and impending. Moreover, when presented with a hypothetical nuclear accident scenario, people express evacuation intentions that exceed official expectations for which evacuation plans were prepared.[29] The high level of concern over the risk of nuclear power and chemical release may be attributable to the public's perceiving the risks as more threatening and catastrophic than natural disasters.[30]

Biases are associated with perceived threat and consequences of technological hazard. Risk consequences perceived as dreaded (feared), uncontrollable, irreversible, or catastrophic are generally overestimated. Public fears may be intense for particular hazards, especially those with low probability-high consequences (such as those presented by nuclear reactor accidents). Imagery of threat in terms of fear or irreversibility of effects heightens the public perception of risk. Recent studies on judgmental biases in risk perception indicate that members of the public tend to overestimate rare causes of death and those with high imagery and to underestimate common causes of death. Accordingly, the risks of accidents, floods, botulism, fire, and homicides are overestimated; risks of death from diabetes, stroke, and emphysema are underestimated.[31] More recently, a proposed taxonomy of technological hazards has identified major biophysical attributes of hazards which may have considerable potential for predicting public response.[32] While such fears may well seem exaggerated compared with "objective" risk probabilities, it is more appropriate to view the assessment of risk by members of the public as proceeding on a different, and probably broader, basis than those incorporated in quantitative risk assessment by experts. In any event, the fear of the public is an objective reality that contributes to stress and emotional disruption

The complexity of technological threats, as augmented by heightened perceptions of risk, results in response patterns that differ from those associated with natural disasters. One study found that during a derailment that had the potential to release chemical substances, a large proportion of the threatened population complied with the evacuation warning even though the risk was perceived to be low [33] In addition, as the Three Mile Island accident has shown, the technical and scientific aspects of man-made threats, the uncertainty surrounding stages of the hazard chain, and lack of familiarity with the hazard result in greater public dependence on governmental authorities and a reduced reliance on social networks. Thus, emergency managers face an extremely difficult situation when confronted with technological hazard events: The special nature of the threat may be result in overresponse by the public and increased dependence on local authorities for information.[34] In this light, Sorensen has argued that emergency response plans for nuclear facilities have been overly mechanistic and have failed to incorporate sufficiently a knowledge of behavior into their design.[35]

Technological Disasters and Their Long-Term Effects.[36] Although a substantial body of sociopsychological research has addressed the effects of disasters on individuals and families, a number of issues have surfaced requiring expanded research. Recent reviews on psychological and emotional effects of natural disaster have identified serious inconsistencies in earlier findings.[37] The work by Erikson, for example, shows that disasters can result in adverse and long-lasting psychological disruptive effects.[38] By contrast, several studies suggest that adverse emotional effects following natural disasters have not been pervasive or have occurred only during the immediate post-impact period.[39] Perry has argued that this disagreement stems from definitional problems over the meaning of psychological impacts, methodological differences among studies, and a lack of attention to explanatory theory.[40]

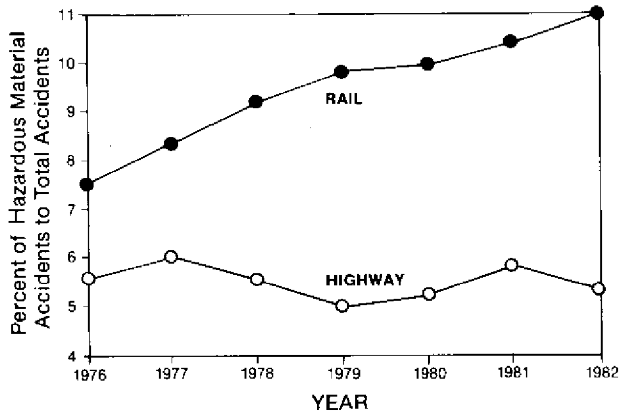
Except for the few major studies on the Love Canal disaster, the Three Mile Island accident, and the Buffalo Creek catastrophe, knowledge of long-term impacts of technological disasters is scant. Behavioral assessments of the effects of Three Mile Island, however, provide evidence of distress during (1) a relatively short period of extreme threat to safety, and (2) a longer term due to impending threats of restart and periodic low-level releases of radioactive material from the disabled reactor unit. The Three Mile Island data point to a high level of distress during the crisis period, but it was relatively short in duration. One study concluded that approximately 10 percent of the surrounding population experienced severe distress equivalent to chronic mental disorder, but such levels declined soon after the accident was under control. In fact, one month subsequent to the accident only 15 percent of the nearby population was experiencing severe distress compared to 26 percent during the crisis.[41] Retrospective assessments of stress six months after the accident found that during the emergency period 48 percent perceived the threat to safety as very serious and 22 percent were extremely upset. However, at the time of the survey, only 12 percent continued to perceive the threat as very serious.[42] A survey of residents revealed that perceived effects on the physical health decreased from 14.4 percent during the accident to 7.6 percent one year later.[43]

Although the incidence of serious distress declined rapidly for a large segment of the population, for others psychological impacts persisted. Immediately after the accident, 24 percent of nearby residents indicated personal consequences of the accident on mental health; one year later 25 percent reported effects on mental health.[44] In 1983 self-reporting workshops held with neighbors of the Three Mile Island reactor found the following effects: "psychic numbing," hopelessness, anxiety, feelings of being trapped by the situation, and lack of peace of mind. These emotional effects were manifest four years after the accident, whereas concern over radiation releases and other threats from the impaired reactor had significantly diminished within one year following the accident.[45] For these individuals recurring reminders of the accident, secondary stressful events such as venting of radioactive substances, and fear of disaster during subsequent operations have resulted in apparently serious continued psychological and emotional effects.

A study of long-term family recovery from natural disaster found the degree of economic loss and lengthy return factors associated with a slower pace of emotional recovery.[46] The Three Mile Island accident, however, did not result in higher levels of permanent unemployment, declines in property values, long-term evacuation and out-migration, or significant economic loss for most residents, including evacuees.[47] In fact, family activities resumed shortly after control of the accident was under way. Thus, reporting on mental health effects years after the accident has to be explained by factors other than delay in material recovery. That radioactive materials were, except for a small amount, contained suggests that the health consequence factor would also not emerge as a critical variable in explaining the prolonged state of emotional upset. Three years after the accident those reporting concern for physical health effects because of Three Mile Island, constituted about 8 percent of the surrounding population, a figure which represents a decrease of 50 percent since the accident.[48]

Speculation on factors influencing prolonged mental health impacts related to Three Mile Island has centered

FIGURE 4
Hazardous Material Transit Accidents, Rail and Highway as Percent of Total Accidents



on the impact of continuous media attention to the issue, perceived risks of intermittent venting of radioactive gases, release of tritium-contaminated water, the threat of restarting the undamaged facility, and the visible presence of the facility as a reminder of potential threat. The perceived threat posed by possible restart of Three Mile Island may present an unacceptable risk situation for some residents. The fear of another accident or a catastrophic accident following restart may be a significant factor. Three years following the accident, over 25 percent of the nearby population believes that the frequency of a major nuclear power plant accident is one in 10 years, whereas in 1979 this figure was only 15 percent. The perceived increased likelihood of an accident within the population is reinforced by the substantial growth in distrust of government regulatory agencies and the perceived lack of personal control in managing the risk.

Threat may be defined as constituting two dimensions —degree of danger (perceived or real) and degree of control. Often with technological hazard, as we have noted above, the hazard chain is poorly understood and the management process fraught with conflict and ill-defined trade-offs. In the few cases of technological disasters, governmental actions have been delayed, ineffectual, and conflict ridden. Individual or group actions by victims to remedy the situation have been generally ineffective. In technological disasters individuals see few opportunities to reduce exposure through physical adjustments because of the pervasiveness of the threat and the "no threshold" level of effects for carcinogens. The perceived loss of control over the hazard event and the inability to undertake adjustments tend to result in anxiety and emotional disturbances.

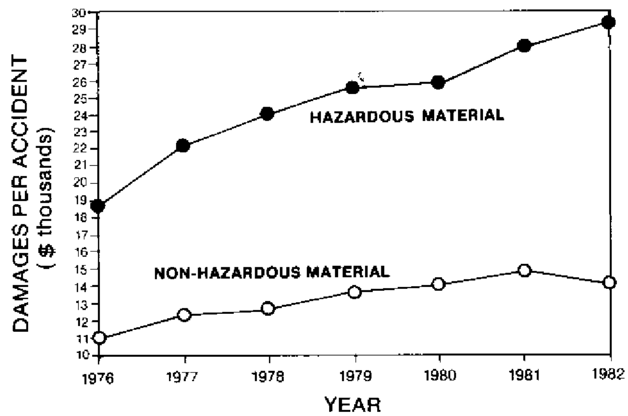
Technological disasters, unlike natural disasters, pose different risk situations and present coping problems that differ from most natural disasters. Attempts to reduce exposure from technological hazards are often difficult because of the pervasiveness of chemical substances and the inability to establish a safety threshold for exposure to carcinogens. There is, further, little experience in defining such threats, forecasting their occurrence and magnitude, and predicting the chronic health consequences. Because of these characteristics, managerial responses intended to produce "blocking" controls or to reduce stress have been ineffective in gaining public acceptance at Three Mile Island.[49]

The "Therapeutic" Community: Natural and Technological Disasters

The emergence of a "therapeutic" post-disaster community—the spontaneous altruism by community victims and non-victims in aid and sheltering activities—has been suggested as one powerful means to reduce disaster-related stress. The therapeutic community emerges in the immediate post-disaster period, because it replaces institutional and organizational resources that are limited or inoperative.[50] The degree of success and the extent of community reliance upon such social innovation requires further research. The therapeutic community has not prevented (1) the most vulnerable groups from suffering proportionately the greatest hardships in recovery, (2) familial stress due to uncertainties prevalent in the early post-impact period, and (3) inequities among social groups in later phases of reconstruction.[51]

Why does the therapeutic community emerge? In areas struck by natural disasters, populations characteristically are differentially affected. Yet, since natural disasters are often perceived as acts of God, victims and

FIGURE 5
Transit Damages per Accident, Hazardous Material and Non-Hazardous Material Accidents



non-victims share a commonality. Loss is directly observable and thus therapeutic response can be focused, defined, and targeted. Additionally, damage caused by the disaster has immediate and perhaps long-term effects on the community's economy and social structure. Erikson suggests that a euphoria often exists in the immediate post-disaster environment which is due to the realization that the community has survived and to a sense of strength in rebuilding.[52] Except for droughts, the onset of most natural disasters occurs relatively quickly and tends to be short-lived. Therefore, energies are focused on recovery; mutual aid systems enhance the rebuilding process.

By contrast with natural disasters, technological disasters, particularly those characterized by prolonged exposure to harmful chemicals, result in attention to activities that will accelerate the decision for permanent relocation and a heightened sense that the community has been destroyed and cannot be rebuilt. The therapeutic community will not emerge when the number of victims exceeds the number of non-victims in the stricken area. For technological disasters, that is typically the case. Additionally, because the problem is caused by humans and the degree of victimization and health consequences are uncertain, the loss is not physically observable, and normal support patterns of care and shelter are not appropriate. In fact, preliminary study of an asbestos disaster in Arizona reveals that visitation patterns to the affected area by non-victimized members of the community and by family and friends residing outside the affected area shifted abruptly and declined.[53] Thus, traditional patterns of social support may not develop in technological disasters.

Aid, rescue, and rebuilding are familiar activities by which communities recover from natural disasters. In such cases, the public recognizes and responds to emotional disruption and physical recovery. Chemical disasters, by contrast, are a new societal phenomenon, and because of the technical nature of the threat, substantial dependence rests on scientific and regulatory institutions rather than on individual family or community efforts. Recovery efforts from natural disasters have revealed some problems in relationships between victims and disaster aid/recovery agencies due to formal agency rules and structures, institutional insensitivity, and delay. In technological disasters, the few situations for which data are available suggest that victim-institutional relationships are often in conflict. At Love Canal, recommendations and actions by EPA awaited a number of scientific assessments of risks. The apparent slow response by regulators, the uncertainty of scientific assessments, and the forced reliance on the media for information fostered deep resentments among victims.[54] If exposure poses risk to only part of a community and there are scientific uncertainties about the nature of the hazard, then the potential adverse impacts on the economy of the area, prolonged debate, political activity among victims, and intense media attention may induce substantial community conflict. Ongoing research on technological disaster reveals that the non-victimized community may develop sharp resentment against the disaster victims.[55]

The sustained threat from chemical hazards, the inappropriateness of traditional coping mechanisms, the dependence of victims on governmental regulatory actions to ameliorate the hazard, and the tendency to blame individuals or institutions as a cause for the suffering have stimulated intense political activity on the part of victims of technological disaster. Political conflict, therefore, should be expected in technological disasters. Whereas such political participation may provide some form of emotional support, the awareness of threat may nonetheless increase over time. The inability of the individual to control the evolving situation may be expected to result in continued or even increased levels of distress.[56] Sorensen and colleagues argue that a number of factors promote harmony during natural hazard events: the conception of the external threat as an act of God; the ability to identify and understand the threat and its impacts; the community identification with loss; and the tendency for community consensus on disaster-related problems and solutions.[57] In technological disasters, a number of factors promote disharmony: exposure to contaminants is pervasive; environmental cleanup measures are often only temporary solutions; and relocation becomes a substitute for recovery.

Conclusions

From this overview and analysis of technological hazards and major hazard events, we reach a number of conclusions:

(1) The major burden of hazard management in developed societies has shifted from risks associated with natural processes to those arising from technological development and application.

(2) Technological hazards pose different, and often more difficult, management problems than do natural hazards. Contributing factors to this greater difficulty are: the unfamiliarity and newness of technological hazards; the lack of accumulated experience with control or coping measures; the less understood hazard chains; the broader opportunities for control intervention; the perceived amenability of technological hazards to fixes; and the simultaneous need to enlarge benefits and reduce risks in judging the tolerability of technological hazards and instituting control strategies.

(3) Hazards may be conceived as composed of a series of linked stages beginning with human needs and ending in adverse consequences. Each stage presents an opportunity for managerial intervention to block or control the emergence of the hazard.

(4) In idealized form, hazard management consists of a sequence of four major activities—assessment, control analysis, selection of management strategy, and implementation and evaluation. Two major functions—intelligence and control—are involved and both necessitate normative as well as empirical judgments.

(5) Technological disasters tend to elicit a different pattern of public response than do natural disasters. Whereas publics tend to be reluctant to evacuate in natural disasters, evacuation from technological disasters tends to exceed official expectations. Factors contributing to this difference are the lack of familiarity and greater perception of threat associated with the latter. Technological disasters, unlike natural disasters, result in a greater reliance upon governmental authorities and a reduced use of community and family social networks.

(6) Although the knowledge of long-term impacts arising from technological disasters is scant, experience following the Three Mile Island accident suggests that although severe distress has been short-lived, other psychological impacts have been persistent. Continual media attention, public perception of risks and threats associated with the restart of the undamaged reactor, and the visible presence of the facility have all contributed to continuing stress.

(7) The emergence of a therapeutic community to ameliorate effects during the post-disaster period appears substantially less likely for technological than natural disasters. Reasons for this include the lack of a sense of rebuilding, priority to relocation as a means of mitigation, conflict between victims and non-victims, and delayed response by government authorities.

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