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TRANSPORTATION ACCIDENTS INVOLVING HAZARDOUS CHEMICALS VERSUS THOSE INVOLVING DANGEROUS NUCLEAR MATERIAL*

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TRANSPORTATION ACCIDENTS INVOLVING HAZARDOUS CHEMICALS VERSUS THOSE INVOLVING DANGEROUS NUCLEAR MATERIAL

In this chapter we focus on transportation accidents which involve hazardous chemicals and those which involve dangerous nuclear material. The chapter is organized into four sections. In the first section, we address the general kinds of risks to people and things which are inherent in the transport of dangerous nuclear material, especially spent fuel. In the absence of a meaningful data base of actual and past incidents, we must posit a hypothetical, future worst-case scenario for the analytical purposes required by the projected comparison. In the second section of the chapter we briefly examine the complete range of possible incidents of chemical hazards in transportation accidents. We observe at this point that hazardous chemicals are far more heterogenous in their potential and, in the extreme case, can be far more dangerous than the risks posed by the worst-case nuclear danger scenario we use. The third section of the chapter is devoted to a discussion of the common and unique functions relating to private and public sector preparations for and responses to both kinds of transportation hazards, as they have been reported in the speculative and research literature. Our general finding is that the two kinds of dangers discussed require somewhat different rather than similar responses. We conclude the chapter with a summary of policy implications for emergency management derived from the functional comparison of the nuclear and nonnuclear hazards discussed in the preceding section. The major conclusion is that despite dissimilarities in the two threats, the existing literature appears to overemphasize technical problems and safeguarding measures, and to underemphasize social and organizational weaknesses in preparing for and responding to transportation accidents regarding both nuclear and nonnuclear hazards.

NUCLEAR DANGERS

What types of dangers can be expected in transportation accidents involving nuclear materials? In the abstract, a relatively simple answer can be provided. However, we shall shortly note that any attempt to be specific generates a number of complexities and uncertainties in all the answers which can be given.

As described elsewhere, we are primarily examining nuclear threats in the context of the nuclear fuel cycle. Viewed in this perspective, there are varying degrees of danger in the transport of materials both to and from nuclear power reactors. As will be documented in the subsequent discussion, the hazards are not nearly as great as popularly believed, but the transportation is obviously not risk-free either.

The operation of nuclear power reactors require the transportation of different types of materials to reactor facilities. In fact, some precautions are necessary at the very start of the cycle. When uranium is extracted from ore during the milling process, there is refuse material, termed "tailings," which contains some residual uranium and most of the uranium decay products which have already been formed from the natural radioactive decay processes. The principal concerns are the radioactivity of radium 226 and its decay product, the gas, radon.

In addition, the Department of Energy has identified other shipments of radioactive materials needed for nuclear plant operations.[1] For example, uranium concentrate made from the ore is shipped from the milling plants in the western United States to facilities for converting the concentrate to uranium hexaflouride. This product is then shipped to a uranium enrichment facility. In turn, the enriched hexafluoride is transported to still other facilities which convert the material to uranium oxide which is then made into fresh reactor fuel elements. The unirradiated nuclear reactor fuel elements are then shipped from the fuel fabricators to reactors.

These kinds of materials do not present serious or major problems even if they are involved in transportation accidents. This conclusion is based not only on theoretical knowledge but also, as will be documented later, on about 30 years of practical experience in handling these nuclear materials. The risks to people and property from transporting such materials to nuclear power plants is quite low; and, even if accidents occur, they are likely to be small in scope and pose minimum dangers.

In both relative and absolute terms, there is potentially more danger in transporting materials away from--rather than to--nuclear reactor facilities. Before discussing these possibilities--and the controversies and complications involved in considering them--we will first note the general nature of the problem. It stems from the fact that nuclear power reactors

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[1]U.S. Department of Energy, Shipments of Nuclear Fuel and Waste... Are They Really Safe? (Washington, D.C.: U.S. Department of Energy, 1978), p. 1.

generate various kinds of radioactive wastes, including spent fuel, at different points in the nuclear fuel cycle. In addition, there are wastes accumulated for over 30 years by the Department of Defense production of nuclear weapons and also wastes accumulated from nuclear-powered ships and submarines.

For our purposes, the solid radioactive wastes derived from the nuclear power cycle fall into the following three categories: (1) the previously mentioned milling tailings, which contain radium 226 and its decay product, the gas radon; (2) spent fuel from reactors which, unless reprocessed for further use as fuel, is highly radioactive; and (3) high-level wastes from reprocessing of spent fuel. There are also low-level solid wastes which may be generated by the use of radionuclides in research activities and for medical purposes.

The more serious hazards derive from spent fuel and high-level waste, in part, because they contain the transuranic elements that have extremely long half-lives. Low-level wastes, contain such low concentrations or quantities of radioactivity that they do not present any significant hazards.[2] But spent nuclear reactor fuel and higher-level wastes are very hazardous because of their intense radioactivity which includes all three types of ionizing radiation (alpha, beta, and gamma).[3]

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[2] Ibid., p. 3.

[3] See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes (Washington, D.C.: U.S. Department of Energy, 1978), p. 1.

At this point, we introduce several complicating factors in the discussion of the hazards involved in transporting nuclear materials. First, the transportation dangers differ in terms of the past, present, and future. For instance, spent fuel was transported in the United States on a fairly large scale up to mid-1972.[4] One fuel cycle service company, Transnuclear, Inc., at a Congressional hearing in 1979, reported that it has "been involved in the movement of over one hundred shipments yearly of spent nuclear fuel from research and power reactors to reprocessing plants in the United States and Europe."[5] As implied in this statement, such shipments of spent fuel have also occurred in other countries, as well as perhaps from other countries to the United States. Since June 1972, however, irradiated fuel from commercial power plants have been stored on site by plants producing it; the sole exception is the shipment of spent fuel to an existing storage facility at Morris, Illinois.[6] A Department of Energy statement that irradiated "fuel elements are presently shipped from reactors to fuel storage sites (for commercial power reactor fuel) or government fuel reprocessing plants (for research reactor fuel and government power reactor fuel)" apparently is a partial reference to activities connected with production

[4]See M. Willnick and T. Taylor, Nuclear Theft: Risks and Safeguards (Cambridge, Massachusetts: Ballinger, 1974), p. 36.

[5]See U.S. Congress, Senate, Committee on Commerce, Science and Technology, Hearings on Nuclear Waste Transportation Safety Act of 1979 (Washington, D.C.: U.S. Government Printing Office, 1979), p. 194.

[6]Ibid., p. 134.

of nuclear weapons.[7] Spent naval nuclear fuel originating from the defueling of reactors on nuclear-powered ships is also still currently transported by rail to the Department of Energy facilities in Idaho.[8]

It is very difficult to estimate the volume of dangerous nuclear material presently transported or likely to be transported in the future. The Nuclear Regulatory Commission (NRC) estimated in 1975 that nearly 2,500,000 packages of low-level nuclear materials were shipped in the United States.[9] However, a Department of Energy publication states that about 80 percent of the shipments involve small quantities of essentially nondangerous nuclear isotopes for use in industry, medicine, agriculture, and research.[10] In the same publication, it is noted that, "the total number of shipments of nuclear materials to and from nuclear power plants in 1975 probably numbered only a few thousand.[11] It is unclear if transportation of materials in connection with the nuclear weapons program comprise shipments unaccounted for in the above totals, or whether the weapons program is not included in the estimates. One indication of the magnitude

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[7]See U.S. Department of Energy, Shipments of Nuclear Fuel and Waste... Are They Really Safe?, op. cit., p. 1.

[8]See U.S. Congress, Senate, op. cit., p. 210.

[9]See _. _. Simmons et al., Survey of Radioactive Material Shipments in the United States (Richland, Washington: Battelle Memorial Institute, 1976).

[10]See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 1.

[11]Ibid., p. 1

of the differences which might be involved, depending upon what is being counted, is a report that in early 1977 the backlog of high-level waste, including spent fuel in temporary storage, consisted of approximately 266,000 cubic meters from Department of Defense programs, but only 2,300 cubic meters from commercial reprocessing programs.[12]

How little nuclear material the private sector may be transporting is suggested by testimony before a Congressional committee in 1979:

> There are today five vendors that have shipping casks available and are offering spent fuel shipping services. The total inventory of casks available in the United States for shipping light water reactor spent fuel consists of 6 rail casks and 11 truck casks. This fleet of existing casks is more than adequate to perform all the anticipated shipping of spent fuel between reactor sites or to potentially available existing storage sites such as the Central Electric Company facility at Morris, Illinois for approximately the next 4-5 years. The vendors presently have a low demand for their services and underutilization of their equipment.[13]

If these statements are accurate, the sheer number of trips and total volume of spent fuel transported on an annual basis, must be very low. A maximum number of 17 transportation casks, even if fully utilized--which apparently is not the case--simply cannot pose widespread threats. (In fact, the Committee was informed that there were only 33 shipments of spent fuel, by either civilian or military sources, in all of 1979.) This is supported by a study which found that over a five-year period there were only 144 transportation accidents involving radioactive material <u>of any kind</u>

[12]See U.S. Department of Energy, Report of Task Force for Review of Nuclear Waste Management, Report No. DOE/ER-004/D (Washington, D.C.: U.S. Department of Energy, 1978).

[13]See U. S. Congress, Senate, *op. cit.*, p. 134.

including nondangerous nuclear isotopes) out of a total of 32,018 incidents.[14] In fact, in only 36 of the transportation accidents was there any indication of release of radioactive materials, with most cases involving only minor contamination.

In the future, the situation in the United States with respect to the transportation of spent fuel will change. Although a final decision regarding reprocessing of spent fuel has recently been further delayed, the intent appears to be to go ahead eventually with the activity. In the interim, while plants are further developed, a Presidential message to Congress in February 1980, recommended that most of the spent fuel in the nation's nuclear reactors continue to be stored near each power plant.[15] The same message also contained the recommendation that one national facility be established where excess fuel assemblies could be stored until a permanent solution was adopted. One projection, even before the recent Presidential action, was that by 1986 the annual rate of spent fuel shipments by rail could be expected to be nearly 20 percent of the total shipments during the last 25 years.[16] Still another study estimates that by the year 2000, the number of shipments to and from nuclear power plants will probably increase by perhaps five to ten times the 1975 level of a few thousand shipments.[17]

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[14]See A. W. Grella, A Review of Five Years Accident Experience in the USA Involving Nuclear Transportation (1971-1975) (Washington, D.C.: U.S. Department of Transportation, 1976).

[15]See New York Times, 13 February 1980, p. 1.

[16]See _. _. Loscutoff et al., Safety and Economics Study of Special Transportation for Shipment of Spent Fuel (Rickland, Washington: Battelle Memorial Institute, 1977).

[17]See T. R. Anderson et al,, Current Status and Future Considerations for a Transportation System for Spent Fuel and Radioactive Wastes (Barnwell, South Carolina: Allied-General Nuclear Services, 1978).

In addition to the problem of spent fuel there is the matter of high-level waste which would be generated by reprocessing. "If at some future time, government policy should permit reprocessing of commercial nuclear fuel, solidified high-level waste from reprocessing will be shipped. Also, solid high-level wastes from existing government or reprocessing plants for national defense nuclear materials will eventually be shipped to the repository."[18]

For purposes of the present analysis, the overall picture appears to be as follows: In the past, the transport of nuclear material proved to be relatively safe. So far as we can ascertain, there were very few potentially dangerous incidents, and certainly no disasters. In fact, in a span of about 30 years of nuclear shipments of all kinds, there has not been a single death or injury attributed to radioactive shipments, nor has there been a release of nuclear materials serious enough to pose a threat of death or injury.[19] The current situation, in which far less nuclear material of a dangerous nature is being transported than in the past, also is apparently not providing events of a dangerous nature. A 1979 study found that in 142 reported transportation accidents involving <u>any kind</u> of radioactive material (under much more strigent reporting requirements and sensitivity than in the past), only 15 resulted in release of materials, and none of these remotely resembled a disaster or even an emergency.[20] In

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[18]See U.S. Department of Energy, <u>Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes</u>, <u>op</u>. <u>cit</u>.

[19]See U.S. Department of Energy, <u>Shipments of Nuclear Fuel and Waste... Are They Really Safe?</u>, <u>op</u>. <u>cit</u>.

[20]F. Tulsky, "Nuclear Waste Shipments Draw Towns' Inc.," <u>Columbus Dispatch</u>, 23 March 1980, p. 9.

the future, as the number of nuclear power plants increase, the volume of highly radioactive spent fuel to be transported will also increase. Thus there will be a greater, although indeterminate, risk from the transportation of nuclear materials. Similar dangers and risk would be involved in the shipment of high-level wastes from reprocessing of spent fuel.

In the light of future uncertainties about ultimate policy decisions and the future risks involved in the transportation of nuclear materials, we are forced in the subsequent sections to utilize a hypothetical scenario. The worst possible case scenario is, of course, seldom the worst conceivable; rather, the worst case projected is usually one that appears reasonable on the basis of current knowledge and informed speculations about the future. The scenario could certainly be wrong in terms of what may actually occur. In fact, the record of such projections, whether relating to wartime or peacetime, is not impressive, as witness pre-World War II scenarios of future war situations.[21] But, in the absence of more viable choices, the use of a seemingly reasonable worst case scenario in the present instance appears justified.

In the case of both the nuclear and chemical transportation disasters to be compared, we assume an unintentional and nondeliberate event. We also will focus on nuclear and chemical disasters involving rail transport. We do not consider accidents involving air, sea, or road transportation.

[21] See R. Titmuss, Problems of Social Policy (London, England: HM Stationery Office, 1950).

The dangerous nuclear materials we are considering cannot, in practical terms, be shipped via aircraft. Shipment of dangerous chemicals and nuclear material can use barges, but such shipments are few compared to truck and train transport, can obviously take place only in relatively few localities, and involve, by law and practice, a specialized organized emergency response pattern.[22] Furthermore, railroads carry, in the aggregate and in terms of any individual shipment, the largest volume and the greatest bulk shipment of dangerous material. Nuclear wastes are primarily shipped by rail,[23] and railroads carry the bulk shipments of highly volatile liquids or gases that are very toxic or extremely flammable. Finally, a focus on railroad accidents is reinforced by the fact that the most data and the largest number of studies deal with that mode of transportation.

Finally, in both the chemical and nuclear disaster situations we discuss, we are limited in being able to take into account all future relevant changes which can occur. In the instance of the transport of nuclear wastes in the United States, there are likely to be considerable changes in packaging and shipping technology, in legal and regulatory requirements, and in emergency preparedness and response plans and organizations in the next 10-15 years, before shipment of dangerous nuclear material is resumed on

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[22] See, for example, the National Oil and Hazardous Substance Pollution Contingeney Plan as administered by the U.S. Coast Guard.

[23] See U.S. Department of Energy, Shipments of Nuclear Fuel and Waste... Are They Really Safe?, op. cit., p. 17.

a large scale. It is also possible, if not probable, that mishandling in the transportation of spent nuclear fuel in countries outside the United States in the same time period, may provide more concrete lessons and specific data than could be given by our hypothetical scenario. Also, significant changes are now occurring in the preparations for and response to transportation accidents involving dangerous chemicals. The situation today is markedly different from the situation just a decade ago, and every year seems to accelerate the changes that are occurring. In the comparative analyses of the chemical and nuclear transportation disasters presented here, we will not be able to deal with many future probabilities and current changes, although some will be noted.

The Nuclear Transportation Disaster Scenario

For purposes of our comparison we draw our hypothetical case from discussions of the general problem by the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), and to some extent, by the Department of Transportation (DOT). Other scenarios are partly touched on in some of the literature.[57] However, the scenario presented is the one most explicitly treated in detail and, in fact, is specifically presented in

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[57] A comparison might be made in terms of statistical probabilities of different kinds of transportation accidents, but this presupposes a numerical data base which currently does not exist. A comparison could also be made of a nuclear transportation disaster involving dangerous chemicals which would primarily result in burns (and most chemicals are hazardous because in a transportation accident they might burn or explode). However, such a comparison presupposes the literature is easily examined along such lines, and that is not the case.

the context of a discussion dealing with "the maximum adverse nuclear effects of a serious transportation accident."[25] The great majority of studies and reports on the question are directly or indirectly supported by agencies (such as the NRC and DOE) with a definite interest in making a case for the expansion and use of nuclear power. It should also be noted that a few public interest groups,[26] and even some railroad representatives[27] have very seriously challenged the basic premises and some of the information and data presented by the public and private groups that have argued the safety of transporting nuclear wastes. We shall return to this point in a different context in the last section of this chapter.

We will use the following as the worst possible hypothetical case: a train accident severe enough to cause a large enough breach of a cask holding solidified high level nuclear waste or spent fuel.[28] According to an AEC study "only about one transportation accident in every two million would be violent enough to cause such a cask breach."[29] Since even in most severe transportation accidents only minor leaks would occur, we posit a major rupture of the cask for the worst possible case scenario. Many trains would carry only

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[25] See U.S. Department of Energy, Shipments of Nuclear Fuel and Waste... Are They Really Safe, op. cit., p. 9.

[26] See U.S. Congress, Senate, Committee on Commerce, Science, and Technology, Testimony of Pollock of the Critical Mass Energy Project, 1979, pp. 175-190.

[27] See U.S. Congress, Senate, Committee on Commerce, Science, and Technology, Testimony by Harris of the Association of American Railroads, 1979, pp. 157-175.

[28] Nonsolidified waste would pose a greater hazard because only cask containment would have to be ruptured and liquids are more leachable than solids.

[29] See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 9.

one cask and the statistical chances of concurrent and equal rupture of two casks are astronomically high, so we also posit major failure or severe damage to only one cask. We therefore project a transportation accident that fits the DOE position that "only in the worst conceivable accidents are there likely to be any release of nuclear materials that could potentially cause injuries, deaths, or expensive cleanup due to radiological causes."[30]

What would be the effects of such a railroad accident? Or in the words of the DOE statement just quoted: "How about the case of the impossible accident, one so violent that the cask shell would be ruptured?"[31] The The answer is that a serious wreck " with as much leakage from the cask as is credible under those conditions"[32] the radiation contamination would be as follows: There would be high levels of contamination within approximately several hundred feet that could have lethal or injurious consequences to exposed people. Beyond about 350 feet, radiation levels would quickly taper off to nondangerous levels. The physical area exposed might be contaminated and continue to present a threat although, because of the dense and relatively nonsoluable nature of the waste, gross contamination of nearby property or water supplies is improbable.[33]

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[30]Ibid., p. 10.

[31]Ibid., p. 10.

[32]Ibid., p. 10.

[33]This paragraph is primarily taken from U.S. Department of Energy, Shipments of Nuclear Fuel and Waste... Are They Really Safe, op. cit., pp. 41-42; and idem, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 10.

The major damage to humans in the context of our scenario would be produced by exposure to gamma radiation, which can travel long distances and can penetrate into and through the body; some of the radionuclides that can be inhaled or ingested also emit gamma rays as well as short-range low penetration alpha and beta particles. Injury is caused by the effect of ionizing radiation in the body. Broadly speaking, ionizing radiation acts more like cumulative toxic poisonings than like physical causes of injury such as blast, missiles, and thermal radiation. Large single doses can cause severe acute sickness or death, depending on the size of the dose and individual susceptibility. Small daily doses can be incurred over extended periods of time without causing illness, although delayed consequences may become apparent in later life.[34]

Obviously the possible deaths and injuries either in the short-run or long-run in the scenario we posit partly depends on the size and duration of exposure, climatological and topological variables, as well as individual susceptibility. However, even if the train accident we project would occur in a heavily populated area, and even if a cask rupture were maximum, it appears likely that such a massive wreck would lead to a speedy evacuation of people in the immediate area. The maximum area of potential danger would be roughly about one city block long. Under almost any creditable scenario posited, it is unlikely that many people would remain in the area for long enough periods of time to incur significant radiation damage.

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[34]The material in this paragraph is primarily taken from Defense Civil Preparedness Agency, DCPA Attack Environment Manual (Washington, D.C.: U.S. Government Printing Office, 1978), pp. 10-11.

A potentially more serious situation can be envisioned if the waste contents of the disrupted cask were somehow quickly diffused over a much larger area.[35] However, it is claimed that even direct impact on a train by such agents as tornadoes, hurricanes, lightning, or earthquakes would not stress casks beyond their design integrity.[36] Furthermore, the duration of exposure is an important element in the exposure factor, so, even if there were radioactive material release resulting from such events--and rupture does not necessarily mean release of dangerous substances, especially with solid wastes--the possible damaging effects, if any, would not likely be immediate. Disastrous events of the magnitude necessary to damage casks would probably be so destructive that the nonnuclear effects would be far more severe than those produced by the nuclear hazard.

An explosion could possibly disperse radioactive material from a ruptured cask. However, the solid, high-level waste, as well as the cask itself, is chemically inert. It is nonflammable, nonpoisonous and nonexplosive--in both the chemical and nuclear sense.[37] Studies of military ammunition explosions on trains suggest that casks would probably not even be knocked off their flatcars, much less damaged by an explosion to a point where a cask might lose its integrity. Under most probable circumstances, it is

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[35]Unconfirmed stories about a disastrous incident in the Soviet Union imply that an explosion of stored nuclear wastes sent a radioactive plume 40 or more miles in one direction. See Z. Medvedev, "Two Decades of Dissidence," New Scientist, Vol. 4 (November 1976), pp. 264-267. However, the incident, if it did happen, was not the result of a transportation accident, and involved nuclear waste storage techniques never used in the United States.

[36]See U.S. Department of Energy, Shipments of Nuclear Fuel and Waste... Are They Really Safe, op. cit., p. 37, 42.

[37]Ibid., p. 37.

argued, a transportation accident involving dangerous nuclear material in connection with an explosion would not directly cause any structural damage and would only possibly contaminate some things.

Existing empirical evidence supports the idea that there is cask integrity under extreme environmental impact. The very few casks involved in transportation accidents (primarily in truck rather than train incidents) have generally maintained their integrity. Experimental tests at the Sandia Laboratories "conducted with spent fuel shipping casks to date shows that there simply is not an accident within the realm of possibility that's going to seriously threaten that cask."[38] Among the tests were a 30 foot drop on an unyielding surface, a 42 inch drop onto a 6-inch diameter steel spike, an exposure to a fire of 1475 degrees F for 30 minutes, and an immersion in 3 feet of water for 8 hours.[39] The claim that the "heavily shielded casks are strong enough to withstand the most brutal of accidents--from a collison with a diesel locomotive traveling at 80 miles per hour to hours of submersion in jet fuel fire" may be only a public relations statement issued by a pro-nuclear energy company, but so far actual accidents and test experiments have not contradicted the position of those who argue for cask integrity under extreme environmental impact.

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[38]See U.S. Congress, Senate, Committee on Science, Commerce, and Technology, 1978, p. 154 (need complete citation).

[39]See U.S. Congress, Senate, Committee on Science, Commerce, and Technology, Hearings on Nuclear Waste Transportation Act of 1979, op. cit., p. 111. However, see Harris op. cit., who testified that at least the fire situation might not have been a maximum test. Studies conducted by the railroad showed that in a selected sample of 44 recent accidents of trains carrying hazardous materials which involved fire, 28 percent burned for more than 24 hours, with two of the fires lasting over eight days.

In sum, by our criterion for each of the defining properties, transportation accidents involving nuclear materials are characterized as having low magnitude of impact, focal scope of impact, rapid speed of onset, and because of possible lingering radiation, long duration of impact.

Chemical Hazards

The picture with respect to the hazards of transporting dangerous chemicals in the United States has many complexities as well. For example, the chemical area involves a tremendously wide variety of potentially dangerous substances with varying and different kinds of potentially dangerous effects. Exactly what and how much is transported is unknown and the picture with respect to transportation accidents involving hazardous chemicals is obscured by a mixture of varying regulatory definitions, different conceptions of what constitutes a hazard, ignorance of rules, incomplete reporting statistics, conscious, illegal ignoring of report requirements, and a vast array of private and public groups, at national, state, and local levels mostly operating with not much concern or knowledge of the other segments. Nevertheless, it is possible to develop a somewhat empirically derived general picture of chemical hazards, because, unlike the nuclear dangers just discussed, we can use as a base certain rough data from actual current situations instead of having to speculate on projections of possible future happenings.

In the United States alone, the chemical industry is about a 150 billion dollar-a-year enterprise. Tens of thousands of different chemicals are manufactured annually with more than 20,000 of them produced in amounts exceeding one million pounds yearly. Several thousand new chemicals are introduced into the commercial markets each year. Given the magnitude of the enterprise, the great number of chemicals, and the continual creation of new ones--and even if only a small percentage of the chemicals involved are dangerous--then obviously there is a substantial and increasing risk problem.

This is the case. Unfortunately the full range of that risk is unclear. Part of the problem derives from the fact that various classification schemes differ rather widely on the chemicals that are designated as dangerous. The National Transportation Safety Board has said that "over 18,000 different hazardous products" are "shipped daily."[40] One writer recently stated that some 1,600 chemicals can be categorized as hazardous "including most of the big commodities that make up the bulk of the industry's output."[41] Clearly the classifications implicit in these statements are not in agreement with the classification of 271 hazardous "substances" in an Environmental Protection Agency (EPA) master list which, in turn, differs with the Department of Transportation (DOT) list of 121 hazardous "materials" under various DOT regulations.[42] However, the basic issue is not whether some chemicals are potentially hazardous to life, well being, property, and objects, but rather how many of a substantial number of them are a threat, in what ways, and to what degree.

[40] See National Transportation Safety Board, Survival in Hazardous Materials Transportation Accidents (Washington, D.C.: NTSB, 1979), p. 24

[41] See J. Winton, "Chemical Cargo," Chemical Week (July 5, 1978), p. 5.

[42] See Hazardous Materials Transportation Task Force, Report (Washington, D.C.: DOT, 1979), p. 17.

Potentially dangerous chemicals exist in all possible forms--liquids, solids, and gases--and can bring about a variety of deleterious consequences, varying with the nature of the physical or biological substance exposed to the chemical. Thus chemicals can do damage independently or through combinations of inhalation, injestion, absorption, contact, and other exposures to flammable materials, compressed gases, corrosive materials, explosives, oxidizing agents (e.g., bleaches and chlorides), poisons, etiologic materials (e.g., liquified natural gas), and molten materials.[43] There are, in short, multiple ways in which human and other organisms, plant life and fauna, and physical and material objects can be destroyed, damaged, or otherwise negatively affected by a dangerous chemical. Furthermore, a number of chemicals which are benign in themselves can, as a result of a synergistic effect or the reaction resulting from mixing with other benign chemicals, become highly dangerous substances.

The available numerical data on the transportation of chemicals (including dangerous ones) in the United States, and on accidents and dangerous incidents associated with the transportation process, are rough estimates at best. For example, the decentralized nature of the trucking industry, the multiplicity of chemical manufacturers, and the involvement of shipping companies independent of both truckers and producers, almost insures that

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[43]The various ways in which different chemicals can affect human beings and material objects are discussed in many sources including handbooks on how to respond to acute chemical emergencies, such as U.S. Department of Transportation, Emergency Action Guide for Selected Hazardous Materials (Washington, D.C.: DOT, 1978).

accurate total figures about vehicular transport of dangerous chemicals is unknown. There is no central registry, and assembled figures are computed from an indefinite set of selective self-reports, incomplete surveys, and limited samples. Also, because of legal, insurance, public relations, and other problems, there is also a tendency, as has been found in some studies,[44] for an undetermined number of accidents never to reported outside the railroad or trucking company involved. To be sure, it is the relatively minor events which do not appear in the statistics. But the end result is still a considerable degree of error in using any quantitative data for study or research purposes--particularly if risk analysis, or examination of potentially serious events and not just actual major accidents, is the focus of attention. A serious problem is that risk analysis models and quantitative projections on the basis of admittedly invalid data[45] are not only produced, but then are often cited and used by others with no acknowledgement or even recognition of the original seriously flawed nature of the study.

Even a recent Department of Transportation task force said of its own departmental hazardous materials incidents statistics:

> The adequacy and relevancy of much of the data are questionable.... The credibility of available incident data is questionable, and there is no routine validation of the data.[46]

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[44]This is reported in the Disaster Research Center newsletter, Unscheduled Events, Vol. 13 (1979).

[45]See, for example, _. _. Jones et al., Risk Analyses in Hazardous Material Transportation (Los Angeles, California: Institute of Aerospace Safety and Management, 1973).

[46]See Hazardous Materials Transportation Task Force, op. cit., pp. 41-42.

Dispite these caveats, the statistics, if used cautiously, indicate crude parameters, rough trends, and some general indications of the problem. The statistics are better than speculations and at least provide educated guesses. They represent actual phenomena rather than projections of hypothetical future happenings. The figures also have a reality of their own, since they are at times taken seriously and at face value by some legislative bodies, concerned citizens and public interest groups, shippers and distributors, emergency organization personnel, and researchers. As such, they help determine what is or is not done, and are part of the general societal climate about the problem.

Although the volume is huge (perhaps several billion tons yearly), estimates of the amount of hazardous materials transported yearly in the United States vary widely and it is also not clear what modes of transportation actually carry what proportion of hazardous materials. Some estimates are that railroads haul about 70 percent all hazardous material. This may be true, for at the close of 1977 there were about 170,000 tank cars in railroad service, just about 10 percent of all freight cars.[47] The hazardous materials most often transported by railroads--such as liquified petroleum gas (LPG), chlorine, anhydrous ammonia, and vinyl chloride--are carried in these tank cars, which have capacities up to 42,000 gallons. About 16,000 of these cars carry LPG, one of the most dangerous chemical hazards, to and from about 8,000 storage facilities

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[47] See National Transportation Safety Board, Safety Effectiveness Evaluation (Washington, D.C.: NTSB, 1979), p. 1.

around the United States.[48] From another perspective it has been reported that about 35 percent of all trains contain hazardous materials,[49] although this would not seem to be consistent with a news magazine estimate that one in every twenty-three railroad cars carries dangerous cargo.[50] Data on truck transport is even less specific, but some estimates suggest that, at any given time, there are at least 100,000 trucks carrying bulk cargoes of hazardous chemicals. Even without including air and barge traffic, it is obvious that the separate potential chemical threats in transportation modes is at least in the six figures. The Southern Pacific Railroad alone reportedly moved over 100,000 carloads of hazardous substances in just one year--1974.[51]

There are varying estimates of the number of hazardous incidents when contrasting reports are issued by different sources, but there is agreement that the great majority of hazardous materials incidents occur on highways rather than on railroads. In reported figures for 1977, for example, there were 14,250 hazardous materials incidents on highways

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[48] See Comptroller General, Report to the Congress--Liquified Energy Gases Safety (Washington, D.C.: U.S. Government Printing Office, 1978).

[49] See Systems Safety Analysis Subcommittee, Phase I Final Report (Chicago, Illinois: American Association of Railroads, Technical Center, 1978), p. 2.

[50] See U.S. News & World Report, 1978. (need complete citation)

[51] See C. W. Bahme, Disaster Control (Boston, Massachusetts: National Fire Protection Association, 197_).

compared with about 1,500 on railroads.[52] Depending on what report is used, 75-90 percent of all incidents involving release of hazardous materials occur on highways, compared to 6.7-10 percent on railroads.[53] Absolute and relative figures for other years consistently show more hazardous material incidents on highways. There is also some limited evidence "that trains carrying hazardous materials are involved in accidents less frequently than other trains."[54]

Whatever the exact statistics, rail and truck accidents involving hazardous chemicals result in major disasters and large numbers of injuries, deaths, and property damage. In 1978, train derailments involving hazardous materials in Waverly, Tennessee, and Youngstown, Florida, produced a total of 24 deaths, 159 injuries, $3.3 million in property damage and $650 million in legal claims. The incidents reported in 1971 through 1977 resulted in 457 deaths, 6,729 injuries, tens of thousands of evacuees, tens of millions of dollars in property damage, and even more millions in legal claims. A recent newspaper article noted that in the first nine months of 1978, a total of 19,713 persons were evacuated from their homes as a result of 783 rail accidents involving hazardous chemicals, including 178 in which toxic chemicals were released.[55] Even when disasters do not occur, there often is major social disruption as when 250,000 people recently had to

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[52]See National Transportation Safety Board, Safety Effectiveness Evaluation, op. cit., p. 5.

[53]Ibid., p. 3. Also see System Safety Analysis Subcommittee, op. cit., p. 2.

[54]See System Safety Analysis Subcommittee, op. cit., p. 3.

[55]See New York Times, 15 April 1979.

be evacuated from the Mississauga in the metropolitan area of Toronto, Canada, as a result of a train derailment threatening the release of chlorine gas.

The overall picture, for purposes of the analysis in this chapter, appears to be as follows. While any strict quantification of the available information cannot be taken too seriously, it is clear that there are a number of dangerous chemicals that can have multiple and complex negative effects. There is reason to believe that the risk and threat from such substances has been and is increasing. The transport of such chemicals creates serious risks, many of which eventuate in emergencies and some in community disasters. Whatever the future may bring, the transportation of hazardous chemicals is currently a serious problem for American society. Along all the lines just indicated, many of the chemical threats pose even greater dangers than the nuclear dangers discussed in the first section of this chapter.

A Chemical Transportation Disaster

As previously noted, dangerous chemicals as a category are much more varied in nature and in their possible effects, and they are more heterogeneous than are nuclear waste materials. Thus an overall comparison of all such wastes with all such chemicals would be to contrast an intrinsically narrow range of similar or homogenous phenomena with a very wide range of quite dissimilar phenomena. However, an across-the-board contrast is impossible in practice, if not in principle, simply because of the thousands of dangerous chemicals which would have to be used for the comparison. But if only certain chemicals are selected from the range for comparative purposes, any differences found may be more a function of the selection process rather than a reflection of the general characteristics of the phenomena themselves.

Thus it is possible to select dangerous chemicals very similar to nuclear wastes, or to select dangerous chemicals whose properties and effects are quite unlike nuclear wastes. There appears to be no close correlation between magnitude, scope, speed, and duration of impact of most hazardous chemicals involved in transportation accidents. In part, because of the many ways in which different chemicals may produce their effects, as discussed earlier, almost all possible combinations of high-low magnitude, focal-diffuse scope, rapid-slow onset, and long-short duration could probably be found by a systematic analysis of the many dangerous chemicals currently being transported.

Nonetheless, the disaster dimensions just noted, do provide a pragmatic way out of this dilemma. As will be explained below, they led us to the selection, for comparative purposes, of transportation accidents involving chlorine. Out of the thousands of hazardous chemicals that could have been chosen, a nonflamable poisonous gas--chlorine--appears to be a defensible choice.

We selected chlorine from a broader list of 42 hazardous materials shipped in bulk in the United States which the U.S. Department of Transportation has thought dangerous enough to include in their basic manual, Hazardous Materials-Emergency Action Guide.[56] Using scope of impact--interpreted in the manual as extent of downwind evacuation potentially required for each of the 42 chemical hazards--we identified five substances falling on the high end of the distribution. Besides chlorine, these were acrodein, baron trifluoride, bromine, and phosgene.[57]

Scope of impact was used to reduce the larger list, in part because the Guide provided a fairly direct measurement of this important dimension of physical impact and related social disruption. It should be noted that potential scope of impact varies considerably for individual chemical hazards as well as the entire range of chemical hazards on the list. Moreover, we reasoned that of the four defining properties of disaster events used in our report, scope of impact would be the least likely to vary in actual nuclear transportation accidents and therefore would be most useful for placing nuclear transportation hazards within the more general context of transportation of hazardous materials.

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[56]See U.S. Department of Transportation, Hazardous Materials-Emergency Action Guide (Washington, D.C.: DOT, 1977). This manual is currently being revised to provide a variety of data on about 2,000 chemical hazards.

[57]In making these selections, we did not consider possibilities associated with the presence of multiple dangerous chemicals on the same train, a very common occurrence in this country. Ibid.

The five dangerous chemicals were eventually narrowed down to two, chlorine and phosgene, since the other three are not generally transported in bulk on railroads. Chlorine was then selected because of its much higher volume of transport and commercial use in the United States and the fact that there was considerably more literature on transportation accidents involving chlorine. Although the statistics varied, depending on the sources examined, the various figures support the conclusion that "the rail transport of liquid chlorine certainly presents a major risk of a catastrophic spill of a volatile, toxic chemical." [58]

Of all the chemicals, chlorine ranks sixth in the United States in terms of total production. In 1972, nearly 100 plants in half of the states produced 9.8 x 10^6 tons, with a growth rate in production at that time calculated to be about 4.5 percent per year. Nearly half of all the chlorine produced is shipped--in 1972 this amounted to 4.44 x 10^6 tons. About 70 percent of shipment is by rail. In 1972 this approximated 42,000 shipments (the 7,000 tank cars used averaged six trips of about 250 miles duration each).[59] All tank cars now being produced have a capacity of 90 tons.

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[58] See J. A. Simmons, R. C. Erdmann, and B. N. Naft, The Risk of Catastrophic Spills of Toxic Chemicals (Los Angeles, California: UCLA School of Engineering and Applied Sciences, 1974), p. 56.

[59] The statistics in this and the next paragraph are taken mostly from Ibid.

In 1974 it was observed that there were approximately five railroad cars per year involved in accidents that resulted in the release of chlorine gases. One estimate is that once every ten years a damaged tank car will erupt, releasing its entire contents to the environment. If that were to happen, about 17.5 percent would immediately flash, while the remaining chlorine would spread over the ground. A related study concludes that "there is about one chance in 100 that 50 to 100 persons will die as the result of a rail accident involving the spillage of chlorine within the next year."[60]

Chlorine is a poisonous but nonflammable gas. It can not catch fire, but it may ignite combustibles and containers of the gas might explode as a result of heat from a fire. The gas vapors, which are greenish-yellow in color, may be fatal if inhaled, and contact may cause burns to skin or eyes. Effects of contact or inhalation may be delayed. Severe, short exposure may cause serious injury or even death (e.g., at concentrations of 1,000 parts per million). A concentration of 40-60 ppm can be dangerous after 30 minutes exposure. Runoff from fire control or dilution water may pollute streams or drinking water supply. Overall, chlorine has been ranked 9th of the most hazardous substances out of 257 materials rated by a complex rating system.[61] In the event of a transportation accident and danger of explosion, the minimum safe distance from flying fragments is 2,000 feet in all directions (although the maximum reported actual fragment distance

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[60]See J. E. Zagic and W. A. Himmelman, Highly Hazardous Materials Spills and Emergency Planning (New York: Marcel Decker, 1978), p. 37.

[61]Ibid., p. 11.

from an exploding tank car so far is 4,900 feet). For an approximate spill of 800 square feet, and prevailing winds of 6-12 mph, distance to evacuate from the immediate danger area is said to be 340 yards, but for maximum safety the downwind evacuation area should be two miles long and one and one-half miles wide. Obviously with larger spills and stronger winds, the safe distances would be farther away. Clearly, a catastrophic disaster insofar as casualties is concerned, is possible with chlorine, given the presence of certain conditions, all of them well within the realm of actuality and possiblity.

In sum, the magnitude and scope of impact for a transportation accident involving chlorine could vary considerably. Thus, depending on circumstances, the impact characteristics of chlorine disasters could be similar to or quite different from the postulated worst case nuclear transportation accident discussed earlier. Finally, its speed of onset would be rapid and duration of impact short by our interpretation of these remaining defining properties of disaster events.

FUNCTIONAL COMPARISONS

The functional comparisons which follow are organized in terms of the time-phase classification scheme developed in Chapter 3. To maintain consistency with the analysis in other chapters, the same time phases are used, but along certain lines there is a simplification forced by such usage. For example, in the case of transportation accidents involving both nuclear wastes and chlorine, there is often a dual impact phase. There is the impact of the railway accident itself, and then the impact of the hazards posed by the two substances. The initiation of the impact phase of the transportation accident can be identical with that of the hazardous agents, but it can also be separated by minutes, hours or even days. Additionally, the railway accident can itself be a separate disaster, independent of any threat posed by chlorine or nuclear wastes. The possibility of two impact times and of a double disaster, with all that implies about preparedness and response to such situations, is less likely in the other functional case comparisons made in this report. Thus a measure of distortion is introduced in using a time phase sequence which assumes one impact time and one disaster agent.

Steady State

1. Hazard-Vulnerability Analysis and Reconstruction Planning

With regard to hazard-vulnerability analysis there is a considerable literature on the general topic with respect to both chlorine and nuclear wastes. In fact, much of the work in the area specifically deals with transportation accidents in which the two substances might be involved. The quantitative studies of risk analysis, which is the predominant thrust of the work, have been done primarily at the national level, for nationwide use. In the case of chlorine, for instance, it would be extremely rare for state or local agencies to attempt to make assessments of a specific chemical agent; they rarely do it for hazardous chemicals as a whole, although some moves in this direction have recently occurred. In the case of nuclear wastes, since a transportation accident might happen almost anywhere, little specific hazard-vulnerability analysis is undertaken at other than the national level.[62] Also, the work done seems to be primarily a research exercise, providing general information and background for emergency planners and operational personnel rather than specific guidelines for details.

A relatively recent study on the risk of catastrophic spills of toxic chemicals is typical. The work focused primarily on the assessment of the probability that transporting chlorine via different modes would result in a single, catastrophic accident having a large adverse impact. The general conclusion was that the transport of chlorine by railroad tank cars poses the most serious risk because of the accident frequency, the large amounts of the chemical shipped by this mode, and the proximity of rail routes to densely populated areas. A tentative estimate was made that in future years, improved safety measures resulting in the reduction in rail accident rates could offset expected increases in population density and the number of chlorine shipments.[63] Other kinds of risk analyses, where chlorine is

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[62]This is not to deny that in some communities, local civil defense offices, for example, may not have attempted to assess the degree of vulnerability of their area to transportation, especially rail accidents, but this kind of activity, studies have shown, is rare. Even in localities dominated by one kind of chemical plant, disaster planning does not seem to be oriented around a particular chemical agent. See the current work of the Disaster Research Center on chemical hazards, e.g., the special issue of Unscheduled Events, op. cit. It would be even more unlikely that chlorine or nuclear wastes would be singled out for special attention. However, in a few states, some examinations have been made of the general transportation of radioactive material in particular states. These have usually been surveys of what is being transported at a given point in time. See Transportation of Radioactive Material in Pennsylvania (Harrisburg, Pennsylvania: Pennsylvania Department of Environment Resources, 1978), or Transportation of Radioactive Material in South Carolina (Columbia, South Carolina: South Carolina State Department of Health and Environmental Control, 1978).

[63]See Simmons, Erdmann, and Naft, op. cit.

usually only one of the dangerous chemicals analyzed, similarly try to project the probabilities and effects of an accident.[64] In the main, most of the work in this area emphasizes the danger and the substantial risks involved in the transport of hazardous chemicals such as chlorine.

The risk analyses done in connection with nuclear wastes stand in contrast. The general thrust of these analyses is that transportation risks are relatively low.[65] They emphasize that the probabilities of something going wrong are small, and that if something untoward were to happen the consequences would be minimal. As in the case of the chlorine studies, there is considerable effort at quantification, although in many cases it is explicitly noted that a variety of uncertain assumptions have to be made about the nature of the data used.[66]

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[64] See Zagic and Himmelman, op. cit.

[65] As example, see L. Q. Anderson, Realistic Assessment of a Nuclear Cask During a Hypothetical Railroad Accident (Barnwell, South Carolina: Allied General Nuclear Services, 1978), or C. V. Hodge, Risk Analysis of Shipments in the Nuclear Power Industry, Proceedings of the 4th International Symposium on Packaging and Transportation of Radioactive Material, September 22-27, 1976, Miami, Florida.

[66] For example, see W. E. Kasterberg, J. E. McKore and D. Okrent, On Risk Assessment in the Absence of Complete Data (Los Angeles, California: UCLA School of Engineering and Applied Sciences, 1976).

There is not much reconstruction planning with respect either to chlorine or nuclear wastes. There are implications from some of the risk analyses that, for example, improvement in rail technology would reduce the dangers, but this is usually translated into structural hazard mitigation measures, such as improving the maintenance of railroad tracks. That the hazard analysis could have policy implications for reconstruction planning is noted implicitly rather than explicitly, and there seems to be little effort to link the two functions directly.

Chlorine is one of the four classes of chemicals which has a nation-wide mutual aid network (the other three being pesticides, hydrogen cyanide, and vinyl chloride). This program, CHLOREP, is organized by the Chlorine Institute, which represents the manufactures of the chemical. The program has 50 trained teams, located at chemical plants around the country, equipped with specially designed emergency kits. Some kits contain valves and equipment to seal leaking cylinders; others contain items needed to stop leaking valves and fittings in railroad tank cars. The different teams, although located at different company plants are on a standby basis to respond to incidents in their designated areas, and not just to accidents involving their own company. These teams, incidentially, are the kinds of groups noted earlier as not easily classified as local, state, or national. As will be noted in the next section on disaster preparedness, planning, and training there are also a variety of other private and public groups which might send teams to a hazardous chemical incident, although most of them would, unlike the CHLOREP teams, have no special expertise on chlorine problems.

Although the functions of hazard analysis and reconstruction planning may seem dissimilar because of the differences in the substances involved, and the interpretation of the degree of risk involved, they are actually quite similar. In both the case of chlorine and of nuclear transportation accidents, they are primarily research activities and not operational tasks. Both functions for both kinds of disaster agents are similar in the kinds of data and the analytical assumptions and methodologies used. Those who carry out the functions are the same types of people (i.e., researchers) operating in roughly the same sphere (i.e., the national level). In both cases the general knowledge obtained is teniously connected with reconstruction planning. Perhaps the best clue to the close relationship between the two research areas is that sometimes risk analysis models and discussions treat all dangerous chemicals and hazardous nuclear material within the same analytical framework.[67]

2. Maintenance of Standby Human and Material Resources

There are specific standby resources needed and available for both chlorine and nuclear emergencies. In the case of nuclear hazards, resources are primarily at the national level in the public sector. Some states have relevant resources for general chemical emergencies, but usually not for

[67]See L. L. Philipson, Risk Analysis in Hazardous Materials Transportation: A Mechanism for Interfacing the Risk Analysis Model with the Hazardous Materials Incident Reporting Systems (Los Angeles, California: Institute of Safety and Systems Management, 1974); and An Appraisal of the Problem of Handling, Transportation and Disposal of Toxic and Other Hazardous Materials (Washington, D.C.: Naval Ship Research and Development Center, 1970).

specific agents, such as chlorine. Local level disaster groups, although there are undoubtedly expectations in the private sector,[68] tend to have more general kinds of resources which can be used in many different kinds of community crisis situations.

There are, of course, standby teams for operating in various kinds of nuclear emergencies, which could presumably be mobilized in the event of a nuclear transportation accident. Thus, in an analysis of possible future shipments of spent fuel and high level waste, the Department of Energy Interagency Radiological Assistance Plan provides:

> Radiological assistance to anyone requesting it. Under this Plan, DOE coordinates Federal, state, and local radiological incident assistance operations, and encourages the development of local capability to cope with nuclear incidents. Emergency teams are provided by DOE, the armed services, state and local public health agencies, and even some police and fire departments.
>
> ... The capabilities of the Department of Defense; Department of Health and Welfare; Environmental Protection Agency; Defense Civil Preparedness Agency, and several additional Federal agencies can be brought to bear on accidents involving nuclear hazards.... The first objective of the teams is to take the immediate action necessary to save lives, minimize injury, and prevent spread of any nuclear materials that might have been released. The teams remain on the scene until the emergency conditions are under control, and to help the return to normalcy after the incident.[69]

In the main, unlike the case of hazardous chemicals, transporting carrier companies take the position that anything involving radiological substances

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[68]On the basis of general knowledge about industry disaster preparedness, it can be assumed that most, if not all, chlorine producing plants have very elaborate in-plant emergency planning which would include standby human and material resources.

[69]See U.S. Department of Energy, Shipments of Nuclear Fuel and Waste... Are They Really Safe, op. cit., p. 43.

should be handled by others. For example, the brochure of the Missouri Pacific Railroad System on the emergency handling of hazardous materials in railroad cars specifies that if a nuclear fuel shipping case is involved in an accident, the on-site response should be led by any guards with the shipment. If no guards are available to take over, except for a minimum fighting of any fire, the shipper should be immediately notified, with most other actions to await arrival of qualified personnel to deal with the emergency.[70]

The planned pattern of response is understandable for, in both cases, specialized equipment, knowledge, and personnel are necessary. Even though the standby resources would have to be used at the local level, the special nature of the resources required, means that the greatest part of the resources have to be maintained at the national level. However, the distinctive nature of the two types of threat make it difficult to see how resources maintained for one could be usefully developed or used for the other. These are somewhat two different worlds here, with both a public and private split, along with special information, skills, and material goods necessary to cope with a chlorine threat that are different from those needed to handle a hazardous nuclear transportation accident. As such, the standby resource function is rather dissimilar for a nuclear and a nonnuclear disaster.

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[70]See Emergency Handling of Hazardous Materials in Railroad Cars (St. Louis, Missouri: Missouri Pacific Railroad Company, no date).

3. Disaster Preparedness, Planning, and Training

In only one sense is it meaningful to attempt to distinguish preparedness, planning, and training for chlorine transportation accidents from generalized chemical emergency preparedness. As noted earlier, chlorine gas, compared with other dangerous chemicals, can provide its own distinctive threats to life, well being, and material objects. In that sense, preparations for chlorine transportation accidents have to take into account that chlorine may help other substances burn, that under certain circumstances its container may explode, that bodily effects may be delayed after first exposure, that fish may be quickly killed if their water is polluted by relatively minute quantities of the chemical, etc.

However, at the local level, whether it be public emergency origanizations or private railroad train crews, specific preimpact preparedness of chlorine transportation accidents are not likely to be undertaken. The best that can be done at the local level is to have or know sources which can be turned to so chlorine can be identified as the threat (e.g., an identifying placard on the tank card), and, if so identified, what should and should not be done (e.g., a manual indicating how to stabilize a chlorine threat or how far persons must be evacuated from a chlorine spill). In short, at the local level (again excluding chlorine producing plants) there is and only can be general preparedness on where and how to find specific information if a chlorine threat occurs. However, such knowledge is important, for relatively quick response is necessary if a minor transportation accident is to be prevented from turning into a major disaster.

Of course, in varying degree, local organizations, either independently or in conjunction with other community agencies, have developed some planning and training for handling hazardous materials, including chemical ones. The pages of the journals, Fire Command and the International Fire Chief, for example, are full of accounts of how this organization or that community has or is preparing contingency plans for various hazards, including chemical agents. The quality of these plans, judged by research findings, varies widely. They are frequently keyed to the location rather than the event.[71] There are few indications how such plans are given operational capability. Most localities would not have or be able to "assemble and collate data that can form the basis for a real operational capability."[72] And, of course, there very seldom is any account of how the plans were actually implemented in real chemical emergencies. But it does appear that interest in planning for general chemical emergencies is very widespread and being given some priority in many communities. However, studies of preparedness planning and of actual responses to chemical transportation emergencies have found little evidence at the local level of good planning, of a capability of going beyond a written document, or of implementation plans in actual emergencies.[73]

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[71]See J. Kerr, "Hazardous Materials and Civil Preparedness," The International Fire Chief (July 1979), pp. 24-25.

[72]Ibid., p. 25.

[73]See K. J. Tierney, A Primer for Preparedness for Acute Chemical Emergencies (Columbus, Ohio: The Ohio State University, Disaster Research Center, 1980). Also E. L. Quarantelli et al., Outlines of a Model for Studying Community Preparedness for Acute Chemical Emergencies, Working Paper No. 57 (Columbus, Ohio: The Ohio State University, Disaster Research Center, 1979).

At the state level, under the impetus of the National Governor's Association in particular, there is also some movement on the chemical hazards front. Many states, for the first time are including chemical dangers as part of their overall emergency planning. However, as a current unpublished study by the Disaster Research Center shows, it is still rare for chemical disasters and transportation accidents to be treated together in state planning. In a few states, some agencies have preempted local operations by developing response teams to be used in future chemical emergencies. Thus, in Ohio, the state EPA maintains an emergency response section which provides responses to spills through engineers stationed at the district office. In both Illinois and Ohio, plans allow the office of the governor to enlist National Guard helicopters for quick dispatching to an emergency site. In still other states, a lead agency such as a department of natural resources, a department of environmental conservation, a pollution control agency, or a civil defense agency, may have a response plan for dispatching a team.[74] Again, as at the local level, chlorine is singled out for special attention.

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[74]See L. Eroebe, "State and Local Response Capabilities for Material Spills Hazardous to a Water Supply," paper presented at the 97th Annual Conference of the American Water Works Association at Anaheim, California, as part of a Special Seminar on Material Spills Hazardous to a Water Supply, May 8, 1977.

Few evacuations have been made of state level planning with respect to hazardous chemicals. How well the plans work in actual practice is unknown. There is some slight evidence that friction and conflict is generated when state level agencies intervene in a chemical emergency, and take over from local groups, especially fire departments. The presence of friction between outside professionals and local amateurs has been identified in the disaster literature as a frequent problem in various kinds of disaster responses.[75]

At the national level, in both the public and private sector, there are agencies and groups which have collected information about chlorine and its threat. In fact, the chlorine producers have their own organization, the Chlorine Institute, which undertakes a variety of tasks, from serving as a clearinghouse to conducting research. There are industrial teams, commercial teams, and public safety agency teams of all kinds, some of which have specialized knowledge about chlorine, or who have been trained to deal with a range of chlorine-type problems. There are also a great number of manuals and guidelines, as well as training courses and films, produced and distributed by various national-level groups. These groups include the National Fire Protection Association, the Environmental Protection Agency, many of the major chemical producers (such as DuPont and

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[75]See E. L. Quarantelli, "Social Aspects of Disasters and Their Relevance to Predisaster Planning," Disasters, Vol. 1 (1977), pp. 98-107.

[76]See J. R. Cashman, "On Site with a Hazardous Materials Team," Emergency (August 1977), pp. 53-57.

Dow Chemical), the U.S. Coast Guard, the Association of American Railroads (as well as separate railroad companies), the National Governor's Association, the National Agricultural Chemicals Association, the International Association of Fire Chiefs, and the Manufacturing Chemists Association. Again, chlorine, since it is deemed a highly dangerous chemical, is often one of the specific chemicals frequently and specifically discussed in the manuals, guides, training courses, and films.

Whether this melange of material is compatible or consistent is far from clear. There is reason to be concerned. As one author recently reviewing some of this material noted: "To complicate the problem, present guides, reference manuals, emergency action plans and hazard criteria are not uniform or compatible with DOT's concept of classes of hazardous materials or their new placard system grouping... Basic concepts such as toxicity, reactivity, flammability or explosive sensitivity are neither universally agreed to nor used in the same context by the various groups with common interest and responsibility in emergency responses."[77] Some of the information on chlorine hazards examined in various sources for the present analysis seemed to be inconsistent even on technical matters. Some references admitted, for example, that "the relationship between injury and chlorine vapor dosage (concentration x time-of-exposure) are not well known."[78]

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[77]See J. O________, "Development of a Transportation Emergency Action Guides for Hazardous Material Incident," Proceedings of the 1978 National Conference on Control of Hazardous Material Spills, pp. 419-421.

[78]See Simmons, op. cit., p. 16.

Apart from whether the information being used as a basis for planning and training is valid or not, there is also an important question on what is being communicated. There seems to be no effort to measure what students learn in training courses and workshops, and from films. Given that there is evidence in general from educational research that what is taught and what is learned may be rather different, the whole question needs in-depth examination. To report, for instance, that the Transportation Safety Institute of DOT conducted 46 classes in 1977 for 2,165 students on how to identify hazardous materials, how to handle hazardous materials incidents, how to coordinate with other agencies for cleaning and disposal, etc., may be telling us less than might appear at first glance.[79]

Similar kinds of questions could be raised about the disaster preparedness, planning, and training for handling transportation accidents involving hazardous nuclear materials. However, there are important differences when compared with the chemical emergency area. The matter of preparing to handle high-level waste or spent fuel material transportation emergencies is somewhat moot, given almost no shipment of such material at present. Presumably, the governmental teams discussed earlier under standby human and material resources would have a capability to handle nuclear waste or spent fuel transportation emergencies. If and when transport of such material is resumed, it could be anticipated that the teams

[79]See Hazardous Materials Transportation Task Force, op. cit., p. 64.

might receive additional training, and that their preparedness and planning capabilities would be augmented. As noted earlier, it is the apparent general policy of railroads to relinquish control over accidents involving radioactive substances to other authorities. Whether this policy should continue to be maintained if shipments of nuclear hazardous materials were resumed on a large scale, and if the worst case nuclear hazard transportation scenario discussed in the first section of this chapter moved from a hypothetical to a possible situation, is a question that should be examined.

There are, of course, some capabilities at both state and local levels with respect to measuring, monitoring, and handling problems of radioactive substances. Earlier civil defense programs trained personnel, provided dosimeters, etc., to local agencies. These capabilities with respect to knowledge, equipment, and expertise are also to be found in some state civil defense agencies. However, there is reason to suspect both the quality and quantity of what might be available, and how evenly it is spread among the hundreds of local communities and 50 states. There does not appear to be much interest among nonnational level organizations to transfer or apply whatever they have acquired for nuclear warfare preparations to transportation accidents involving hazardous nuclear material. Thus, there is not a counterpart in the nuclear area of the great number of local and state groups who, in varying ways, are involved in emergency planning for chlorine chemical emergencies. The core of nuclear-oriented personnel, resources, and programs would seem to exist at the national level. On the other hand, one of the results of the Three Mile Island nuclear power plant accident has been a considerable intensification of the focus on nuclear matters by many state agencies and a number of local groups. Thus, the overall picture may be changing. However, as was written in 1978, "development of collateral plans and capabilities on state and local levels has lagged behind Federal programs to a marked degree.[80]

Another issue involved here is a very central one about federal policy with respect to all kinds of emergencies. The responsibility for dealing with many kinds of major disasters and accidents have now been centralized in FEMA, but it has not taken over or been given responsibility for the full spectrum of hazards. The FEMA appears only to have looked at its possible role in acute and chronic chemical emergencies, and it seems to have only a partial role in the full range of possible nuclear emergencies. It is also not clear how much FEMA will be involved in preparedness, planning, and training with regard to chemical and nuclear threats, as compared to its role in responding to emergencies in which these elements are involved. FEMA's relationship to the Environmental Protection Agency with respect to chemical hazards and its relationship to NRC with respect to nuclear dangers apparently has not yet been precisely defined.

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[80]See D. G. Darr, "Emergency Response to Transportation Accidents--An Overview," paper presented at the Fifth International Symposium on Packaging and Transport of Radioactive Wastes, May 8-12, 1978.

Centralization of responsibility is one thing, undertaking disaster preparedness, planning, and training across-the-board for all hazards is another. Since different chemical hazards such as chlorine require different kinds of specific preparations and planning than other kinds of dangerous chemicals, putting all dangerous chemicals together as a class and then combining them with the problems associated with hazardous nuclear material, might be rather complicated. In addition, in the transportation area there are a variety of federal agencies which have long and deeply rooted responsibilities and involvement with different modes of transport. Whether responsibilities should be divided, and whether the disaster preparedness, planning, and training could be combined, and how this should be done, if it were desirable and possible, is not easily answered. As it stands now, this function with regard to the transportation of chlorine (as part of the general chemical area) and dangerous nuclear material (as part of all radioactive substances) is divided and unclear. It is important also to keep in mind that there are large and important elements from the private sector involved; in fact, as far as chlorine (as part of chemical hazards) is concerned, the greater part of the preparedness, planning, and training is located in that sector. On balance, combining this function for the two disaster agents seems unlikely, would be extremely difficult to implement, and might not necessarily make for greater efficiency and effectiveness.

4. Public Education and Information

Very little information has been provided to the public at large on transportation accidents involving either hazardous nuclear materials or chlorine. There is a function here that in principle could be filled, but, for the most part, it is not being filled appropriately at the present time. Except for the general admonition that evacuation is a key form of protective action, the content of public education and information programs would have to be different because of the distinct nature of the two hazards and safety precautions related to minimizing their impacts. For example, the dangers from spent fuel or high level nuclear wastes cannot be sensed by sight or smell, whereas chlorine gas can be quickly noted by its yellow greenish appearance and its odor. Likewise, on the whole, shorter periods of exposure to chlorine can be more damaging than exposure to nuclear wastes, while clean-up of chlorine can be far more easily accomplished than decontamination of nuclear radioactive materials.

5. Hazard Mitigation--Structural

A great deal of research and other work has been done on structural mitigation measures in an attempt to prevent or reduce negative consequences of transportation accidents involving both chlorine or hazardous nuclear material. The major attempt has been to improve the tank cars in which the chlorine is carried, and to work on possible improvements of the casks and containers in which dangerous nuclear material would be shipped. The effort is conducted almost exclusively at the national level and understandably so--it is simply nothing in which state or local entities could participate, except perhaps as local groups doing research for the federal government or the railroad industry, or as local units of the rail carriers modifying cars or casks.

For a period of time, railroad tank cars for carrying chlorine were produced with 16, 30, 55, 85, and 90-ton capacity, and with varying kinds of insulation, pressure relief valves, and jacketing. At present a standardized type of car is being produced.[81] Whether the use of the larger cars, which are better designed structurally, compensates for the risk of a greater disaster if one is involved in a transportation accident is unclear. On November 22, 1978, the National Transportation Safety Board, following a train derailment in Youngstown, Florida, involving a chlorine leak, which killed eight persons and injured 135, recommended that all DOT 105 tank cars (which are used to carry chlorine gas) be retrofitted with shelf couplers. However, in the absence of agreement by the Federal Railroad Administration and the Materials Transportation Board, nothing had happened as of a year later.[82] This example illustrates differences within the federal government on what constitutes effective structural hazard mitigation.

There is a vast literature on the design of containers, cannisters, or casks for carrying high-level nuclear wastes or spent fuel. The general theme that comes through is that possibly there cannot be much greater structural safety built into the casks, either because incremental gains in safety would be so minor, or because the gains would be so disproportionate to

[81] See Simms et al., op. cit.

[82] See Office of Evaluations and Safety Objective, Safety Report on the Progress of Safety Modifications of Railroad Tank Cars Carrying Hazardous Material (Washington, D.C.: NTSB, 1979).

the additional costs or efforts. Thus, NRC studies have "led to a conclusion that to go any further in container design integrity ...would not be worth the effort in terms of gain in public safety."[83] No shipping cask specifically designed for high-level waste has yet been built, because shipments of such nuclear waste will not begin for an indefinite period. However, containment and shielding requirements have existed for years with the historical use and shipping of nuclear materials. When a high-level waste shipping cask is built to enclose the waste canisters, it is expected to be almost identical to some current spent-fuel casks.[84] As already indicated, experiments with and the shipping record of spent-fuel casks over a 30 year period suggest a very high degree of structural safety.

Although not specific to chlorine or hazardous nuclear material transportation, there are also ongoing programs to improve and upgrade railroad tracks, signals, rolling stock, etc. To the extent these efforts are successful, the probability of accidents and the ensuing negative consequences should be reduced. However, it is not clear whether these general structural improvements in recent years have in fact had much effect in reducing accidents and their consequences.

There is little similarity in structural hazard mitigation for chlorine, dangerous chemicals generally, and nuclear materials. All are transported

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[83] See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 14.

[84] Ibid., p. 4.

by rail, but the differences between the hazards and the technology for dealing with them are so pronounced that attempts to relate or combine this functional aspect is neither meaningful nor possible. Likewise, there would seem to be little significant activity possible with respect to this function below the national level.

6. Hazard Mitigation--Nonstructural

There is considerable activity involving nonstructural hazard mitigation measures with respect to transportation accidents involving both chlorine and hazardous nuclear material. This activity falls largely into two general categories, rules and regulations associated with the routing of the material through certain localities. The rules and regulations exist at local, state, and national levels and are very complex,[85] not clear to all, and almost necessarily violated in some way. One source lists ten major federal acts alone and two executive orders which have generated many rules and regulations, and the list is far from complete.[86]

The transportation of nuclear material is subject to both the regulations of the Department of Transportation (DOT) and the NRC. Additionally, while transport of such material by the military is under the control of the Department of Defense (DOD) the DOD says that it adheres to DOT regulations. For spent fuel and high-level wastes, the regulations are that the containers must be designed to dissipate heat from radioactive decay. For spent fuel,

[85] For a recent effort to summarize the rules in the nuclear area, see R. F. Barker, Regulatory and Other Responsibilities as Related to Transportation Accidents (Washington, D.C.: U.S. Nuclear Regulatory Commission, 1977).

[86] See Zagic and Himmelman, op. cit., p. 91.

they must be designed to prevent nuclear criticality under both normal transportation and severe accident conditions. NRC issues a certificate of approval prior to use of container designs only if regulatory requirements are met. A type B container, for example, must be designed to retain its contents during severe transportation accidents. In addition to package design, DOT rules specify certain kinds of information must appear on bills of lading, other shipping papers, and the packages themselves. There are also rules which require examination prior to each shipment, including tests for leak tightness where necessary. Shippers, are also required to determine that each container meets the approved design specification.[87] There is considerable redundancy of safety features on production and use. The DOE conducts routine inspections and appraisals of its prime operating contractors. The NRC does the same for private nuclear industry licensees. During those inspections, the DOE and the NRC determine whether safe shipping procedures are being followed.[88] Thus, if shipments of high level nuclear wastes were to restart, all of the above rules and regulations (which already apply to spent fuel shipments) would presumably prevail: There is no apparent need to generate new rules or regulations.

Transportation of hazardous chemicals, including chlorine, also comes under a variety of rules and regulations, although these are somewhat less

[87]See U.S. Department of Energy, Shipments of Nuclear Fuel and Waste... Are They Really Safe?, op. cit., p. 3.

[88]See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 23.

stringent than for nuclear material and are more open to the initiative of private industry in improving packaging safety. In particular, vehicles carrying hazardous chemicals are required by DOT regulations to carry placards identifying the nature of the chemical threat. The placards identify in words and pictures the nature of the potential hazard. The placard for chlorine gas carries a skull and crossbones and in block letters the word CHLORINE. In addition, an international, four-digit numeric code to identify a hazard such as chlorine is currently being implemented. The numbers are intended to be used as a quick reference to a hazardous materials emergency response guide being prepared by the DOT. Standardized names and descriptions, as well as the DOT hazard classification are supposed to appear on the documents accompanying the shipment.

Federal law, notably the Federal Railroad Safety Act of 1970 and the Hazardous Materials Transportation Act of 1974, insures that federal rules and regulations supersede all others, and, for the most part, prevent lower level governmental entities from enforcing legislation not consistent with the national interstate commerce laws.[89] However, different states have different laws governing the transportation of hazardous materials. Many of them have a licensing system for the transport of hazardous material, especially of an intrastate nature, which is not covered by the federal law.

One nonstructural mitigation measure which has recently become the subject of much controversy concerns the equipment used for and the routing of

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[89] See Jones et al., op. cit.

hazardous cargoes. While the topic is far more relevant to trucks than trains, the latter mode of transportation has been involved in the dispute. The general DOE and NRC position is that special rail cars, dedicated trains, regulated or limited speeds, the prohibition of multiple loads, assignment of guards, designation of car placement,[90] or circuitous routing to avoid cities and congested areas for shipment of dangerous nuclear material--all of which have been advocated--is neither necessary nor worthwhile.[91] The general safety rules that railroads already have to follow are deemed enough and nothing new needs to be added for subsequent hazardous nuclear transport: "There are no specific regulatory requirements with regard to routing of hazardous materials by rail."[92] This is the official position taken now for the transport of high level waste if and when it is again intiated. The only concession appears to be that DOE has worked out an agreement with the Federal Railroad Administration for the latter to handle track inspections on a priority basis for those routes over which waste casks will travel.[93]

The melange of rules and regulations, at all levels, and in both the public and private sectors almost insures no one could possibly be aware of

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[90] See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 17.

[91] Ibid., p. 18.

[92] Ibid., p. 48.

[93] Ibid., p. 48.

all the requirements. One indication of the complexity with regard to rules and compliance is that the National Transportation Safety Board recently estimated that "there are more than 2 million employees of shippers, packagers, and carriers who must be aware of and know how to comply with the regulations for the transportation of hazardous materials and any amendments to those regulations."[94] It probably also means that most shipments are at least in technical violation of some law or administrative regulation. More important, studies have clearly shown that there are both deliberate and nondeliberate violation of the rules. Packages and packing are not always perfect; placarding is not always correct or complete; documents are frequently unclear or incomplete. These are only a few of the common regulatory problems uncovered by research studies and the monitoring efforts of regulatory groups.

The whole operation of nonstructural hazard mitigation appears to need a complete reassessment. A major objective of any reassessment should be to provide guidelines for distinguishing among nuclear and chemical shipments in terms of their degree of hazards. But the issue of what rules and regulations should apply to rail transport is not independent of those required in other modes, especially truck transportation. Whether it is possible to combine measures relevant to transporters of both dangerous chemicals such as chlorine and of hazardous nuclear material is unclear; along some lines there are importance differences, but there are also some

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[94]See National Transportation Safety Board, Special Study. Noncompliance with Hazardous Materials Safety Regulations (Washington, D.C.: NTSB, 1979), p. 11.

similarities. Moreover, the question as to whether federal rules should supersede state and local requirements or whether additional requirements are needed at these lower levels is not easily answered. There is also the issue of how to integrate governmental rules and regulations with rules and regulations of private producers, shippers, and carriers of dangerous substances.

7. Insurance

Insurance with respect to the transportation of chlorine is covered under general clauses pertaining to the shipping of any hazardous cargo by rail. It is a national-level function lodged mostly in the private sector, and has little meaning at state or local levels. Insurance regarding the transportation of nuclear wastes or spent fuel is part of a special case, backed by the federal government, in connection with the movement of any nuclear material. It is a national-level matter shared between the public and the private insurance sector.

In principle there is no difference as to who is responsible for an accident, irrespective of what is being carried on a train. The carrier is normally held liable for damages to persons or property occasioned by an accident. This would include costs for property damage, clean up, evacuation, and claims for deaths or injuries. If the carrier can show that the shipper was at fault or at least contributed to the losses, then the shipper may be held partially responsible and may even end up shouldering the full liability.[95] Railroad companies, of course, purchase insurance

[95] See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 45.

from private insurance companies. Transportation accidents involving chlorine are covered under such private insurance arrangements.

The transport of nuclear material, however, falls under the provisions of the Price-Anderson Act of 1957. This provides federal government indemnity to complement available private financial protection for the payment of public liability claims for personal injury and property damage resulting from a nuclear accident. In 1957 two nuclear liability insurance pools were formed by the insurance industry with a combined insurance capability of $60 million applicable to any single nuclear incident. In general:

> The Price-Anderson Act of 1957 provided Government indemnity in the maximum amount of $500 million. The statute further provides that this $500 million shall be reduced by the amount by which the "financial protection required" exceeds $60 million. Thus, the total at any given time is determined by adding the amount of insurance available from the industry (currently $110 million) to the $500 million maximum Government indemnity, and then subtracting the amount by which the available insurance exceeds $60 million...coverage is provided to certain contractors and licensees of the NRC and would be available for payment of public claims for personal injury and property damage in the event a nuclear incident occurred in the performance of activities under the contract or license. This coverage is also available to carriers transporting radioactive waste to and from indemnified facilities.[96]

In over 20 years of insurance coverage of nuclear energy liability, only 11 accidents involving transportation have been reported, and, of these, five involved no claims and four others involved property damage totaling $7,500.[97]

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[96] Ibid., pp. 45-46.

[97] See Barker, op. cit., p. 9.

It might be possible to argue that insurance coverage for transportation of chlorine (along with other dangerous chemicals) should be backed by the federal government as in the case of nuclear hazards. However, a move in that direction would raise fundamental questions about the role of the private insurance industry in American society, the extent of responsibility that the federal government should assume for any risk, and what gains, if any, there would be to anyone. At this time, there appears to be no obvious need for federal government backing of insurance for chemical hazards such as chlorine.

Steady State Conclusions

1. The bulk of the work on hazard-vulnerability analysis for both hazards involves quantitatively based risk analysis studies that employ similar kinds of frameworks, assumptions, data, and methodologies. This nationally based research function is therefore very similar for both the nuclear hazard and the chlorine hazard cases.

2. Reconstruction planning with respect to either chlorine or nuclear waste hazards is not well developed and not informed by the general knowledge obtained from hazard-vulnerability analysis.

3. Maintenance of standby human and material resources are largely dissimilar across the two hazards, both in terms of the information, skills, and equipment needed to cope with these hazards and in terms of the maintenance of these resources in the public and private sectors.

4. There is no counterpart in the nuclear area to the large number of state and local groups (public and private) who are variously involved

in emergency preparedness, planning, and training. The technical requirements of nuclear hazards are different in many ways and the core of nuclear personnel, resources, and programs exist at the national level. Although possible for some aspects of emergency response, particularly at the local level, there are strong arguments against attempting to integrate current preparedness, planning, and training programs.

5. Except for the general admonition that evacuation is a key form of protective action, the content of public education and information programs would have to be different because of the distinct nature of the two hazards and the safety precautions needed to minimize their impacts.

6. There is little similarity in structural mitigation for chlorine, dangerous chemicals generally, and nuclear materials. All are transported by rail, but the differences between the hazards and the technology for dealing with them are so pronounced that attempts to relate or combine this functional aspect are neither meaningful nor possible. Likewise, there appears to be little significant activity with respect to the structural mitigation function below the national level.

7. There are both similarities and differences in what are now largely separate nonstructural mitigation techniques directed to nuclear materials and hazardous chemicals. It is highly uncertain whether these measures should be integrated. It appears that any attempt should be preceded by a complete reassessment and perhaps simplification of nonstructural mitigation programs and techniques related to the transportation of hazardous materials generally.

8. Insurance with respect to these two hazards is clearly dissimilar because of the special backing of the federal government (through Price-Anderson legislation) in the movement of any nuclear material. At this time, there does not appear to be any obvious problem in the way the insurance function is handled for chemical hazards to suggest the need for federal government backing.

Prediction-Warning

1. Issuance of Predictions and Warnings

In any meaningful sense of the term, there can be no predictions with respect to transportation accidents. The notion of warning in the context of such accidents can only have reference to alerting people to possible subsequent dangers produced by the initial transportation accident. As noted earlier, there is a dual disaster implication in the case comparison we are making, and there may be some time delay between the impact of the transportation disaster and the start of the chlorine or spent fuel high level nuclear waste disaster.

There are many similarities with respect to warning about either of the hazardous disaster agents. There is the matter of identifying that there is in fact a chlorine or dangerous nuclear material threat. In the case of chemical disasters, research has established that people who first reach the accident scene are very often unaware of the fact that further dangers may derive from a train wreck or derailment.[98] Unless there are

[98] See the report on the Disaster Research Center work on chemical hazards in Unscheduled Events, op. cit.

obvious sensory clues, such as a peculiar odor or visible gas, there is a tendency to assume that the wreck or derailment comprises the final disaster impact. Thus there usually is a delay in the identification of the specific chemical threat. Even for fireman and other emergency personnel this delay may be lengthened for several reasons. Placards are not always in place, are incorrect, or have been destroyed in the accident. Unlike some others, the chlorine placard clearly spells out the chemical involved, and the skull and crossbones communicates to most everyone who sees it that something dangerous is involved. Train crew members may not be available for questioning and, even if they are, they are not always knowledgeable about the materials being carried. Invoices and loading documents may not be easily located, can be destroyed in the accident, or, even if found, can sometimes not be read or understood. There are even occasions when train crew members, while notifying their own headquarters or dispatching centers, will delay informing local emergency organizations about the nature of the chemical threat. Thus identification of a chemical hazard and the nature of the danger is often a complicated and lengthy process.

Our hypothetical nuclear case scenario could involve all these same problems of identification; there is no obvious reason to think otherwise. In fact, the identification problem would probably be compounded by the absence of any visible cues from radioactive substances. Since it would normally take a massive wreck to threaten cask integrity, the resulting debris and clutter might make it even more difficult than otherwise to notice and identify that a spent fuel cask had been breached by the accident.

In the majority of cases, local emergency personnel and the train crew would have to identify the possible danger. Distant groups at state or federal levels normally would not be directly involved with this function during this time phase. However, railroads are currently developing a procedure which could make emergency response data available before the need arises. Thus a listing of cars, provided to the conductor and engineer of each train, identifies the location, destination and cargo of each car in the train. Taking advantage of the abilities of computers, railroads are beginning to put emergency action information for hazardous cargoes on their lists. A quick look at the list tells the conductor where the hazardous materials are located in the train, and what specific emergency action may be required in the case of spill, fire or other exposure."[99]

Overall, the function of warning is rather similar in both kinds of disasters being considered. In both cases local emergency personnel may have problems in identifying the danger, and the handling of warnings in both the hazardous chemical case and the case involving dangerous nuclear material are probably more closely matched than on any other function discussed in this chapter.

2. Disseminations of Predictions and Warnings

There are, however, some slight difference regarding the dissemination of preimpact warnings in the two types of disasters. (Predictions, again,

[99]See Transporting Chemicals Safely, 1980, p. 18. (Need complete citation) It should be noted, however, this system is very far from being fully installed, and how it will actually function in practice is yet to be tested.

are irrelevant in this context.) Studies have shown that people are much more likely to believe warnings if they are confirmed by their own senses. Such confirmation could easily occur in many chlorine transportation accidents, but would normally not happen in a railroad accident involving dangerous nuclear material. This situation may be changing, however. There is evidence from studies of the Three Mile Island nuclear plant accident and other technological accidents, that the American populace has become very sensitive to possible radiation threats (as well as chemical agent threats). In the future they may be more willing to believe a warning and take protective action for a radiation threat than for a natural hazard. The matter of how the American people currently view technologically related dangers needs further study before a definite conclusion on this subject can be drawn.

The dissemination of warnings in both disaster situations would have to be by personal contacts, flashing lights, loudspeakers, or the use of such public altering devices as sirens. The usual mass media sources are normally not quick enough to provide timely warning of transportation accidents. A possible problem of having to depend on personal contacts or short-range mechanical alerting devices, derives from the fact that the first emergency personnel to appear on the scene (which in some cases could be only one police officer) would have difficulties in quickly warning a large population around the transportation accident site (e.g., if the neighborhood has large apartment complexes). Usually such emergency personnel have

[100] See Brunn *et al.*, *op. cit.*, and *Unscheduled Events*, *op. cit.*

little difficulty in alerting authorities on the nature of the situation if they have correctly identified the threat.

3. Evacuation

4. Protective Action

Everything else being equal, it is highly probable that the evacuation of the threatened populace would have to be on a larger scale for a chlorine accident than for a nuclear accident. Various estimates indicate that with weak wind conditions it would be possible for a fatal concentration of chlorine gas to cover a roughly circular area of a little over one mile in radius. With higher winds the shape of the area covered would become elongated and might reach several miles down wind. This assumes gradual spillage from one standard-size tank car. If there was an explosion of the chlorine tank itself, the lethal area might be much longer. In both instances, we have referred only to lethal effects. In planning evacuation for maximum safety from injuries as well as deaths, however, the evacuation boundaries would have to be extended much farther. For example, in Mississauga, Canada--where there was a threat of an explosion involving one 90-ton tank car which was leaking chlorine--approximately 60 square miles and nearly 250,000 people were evacuated.[101]

[101] See Simmons, op. cit.

In the instance of the nuclear transportation scenario previously posited, in contrast, the area that would need to be evacuated would be much smaller. As noted earlier, almost irrespective of the time of exposure, "beyond 350 feet, there would probably be no radiation injuries at all."[102] Even within 100 feet of a ruptured high-level nuclear waste canister, a lethal exposure would take an hour or more. Thus far fewer people would have to be evacuated for a much shorter distance for a nuclear accident than for a chlorine accident. This has other implications for the nature of the evacuation movement. In the instance of a nuclear accident, people would evacuate by walking away; in the case of chlorine the potentially greater distance might involve having to transport evacuees by motor vehicle.

Evacuation would be the primary protective action for the general population for both kinds of disasters. For the local emergency personnel who first reach the scene, for the train crew, and for others who might be around the immediate site of the transportation accident, appropriate masks and dosimeters might not be available and, if available, their effective use would depend on adequate predisaster training.

Overall, the functions of evacuation and protective actions are somewhat different in the prediction-warning phase of the two disasters in the sense that different knowledge is appropriate and necessary. A central question is whether those involved in the emergency requirements for evacuation and other protective actions would correctly perceive the

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[102] See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, *op. cit.*, p. 41

situations and act accordingly. There is some evidence, for example, that personnel from emergency organizations are often uncertain in many chemical disasters on how large an area should be evacuated. This is a decision local personnel frequently have to make on their own in an early stage of an emergency.

5. <u>Mobilization of Emergency Personnel and Resources</u>

In the vast majority of cases, local emergency organization personnel will usually come upon the scene of a transportation accident as a result of direct patrol, being notified by citizens, or, more rarely, by being notified by railroad personnel. The first emergency personnel to arrive at the scene tend to be from police forces. Thus the degree and kind of organizational mobilization developed to handle the threat is crucially dependent upon the initial perceptions and definitions of the situation of the first police personnel to arrive on the accident site. If there is any fire, or if the transportation accident is seen as involving hazardous materials, fire department personnel may also be among the first to respond. Thus, a few emergency personnel who are first on the scene are crucial in providing the feedback which will effect the mobilization and activities of other emergency personnel and groups. Local agencies will normally not have any other source of information (apart from calls from the nearby public, which usually consist only of general statements to the effect that there has been a train accident). Since train crew members, if possible, would quickly notify their headquarters of the accident, there would be cases where organizations located at great distances from the accident site might be mobilizing for a chlorine or nuclear accident before local emergency personnel have even discovered the transportation accident, much less identified the hazardous material threat.

What is distinctive about the whole prediction-warning phase in the disasters we are considering, is that the potential danger is located in one specific place--even though the threat is not always immediately identifiable--and that warning and evacuation are usually heavily dependent on the perceptions and actions of a few local first emergency personnel who respond to the event. There are many similarities in the functions in this time phase for both types of disasters, except that the nuclear threat would give no visible sensory cues, thus potentially affecting the way in which this function is performed.

Prediction-Warning Conclusions

1. In any meaningful sense of the term, there can be no prediction with respect to any transportation accident. But there are many similarities across these hazards with respect to issuing and disseminating warnings to threatened populations following the initial transportation accident. The warning problem might be compounded for the nuclear transportation hazard because of the absence of visible cues of the radioactive release.

2. Evacuation of the threatened population would be the primary protective action normally possible for both hazards. In a comparison of reasonable worst case scenarios, the magnitude of the evacuation problem would likely be greater for a chlorine disaster. The local performance of this function generally should be similar across the two hazards, but differences in their impact characteristics must be recognized.

3. There is much similarity across these hazards in the mobilization of emergency personnel and resources at the local level of response. However, the nuclear hazard would give no visible sensory cues, thus potentially affecting the way in which this function is performed. The state and national levels of response would not yet have been mobilized for either hazard during this time phase.

Impact

The disasters assumed here for analysis and comparison may, of course, completely skip the prediction-warning stage, and start with impact. That is, the transportation accident and the consequent chlorine or hazardous nuclear materials threats may be concurrent. Chlorine gas could immediately start to leak and diffuse at the time of the train wreck; similarly, a spent fuel waste cask might be damaged and radioactive materials may start to spread at the moment of a train derailment.

1. Evacuation

2. Protective Action

These previously discussed functions continue during the impact, but the differences rather than the similarities between the two hazards become more apparent. The chlorine gas could continue to spread, necessitating the evacuation of a wider area. If there is actual impact, the presence of chlorine gas will become more obvious because it can be smelled and because it can be seen if in heavy concentration. On the other hand, the high-level nuclear waste or spent fuel material would still present no sensory cues, is less likely to spread than chlorine, and is less likely to affect a wider area than it originally threatened. Local resources should normally be able to handle the evacuation process in both disasters, with the efficiency and effectiveness of the evacuation being dependent on the capabilities and preparedness planning of community. Based on the findings of previous research, there is no reason to expect any panic flight.

Evacuation would continue to be the primary protective action for the general population. However, with identification and knowledge of the threats, certain hazard-specific protective measures could be taken by the emergency personnel in the immediate vicinity of the transportation accident site. For example, ordinary gas masks can be used with chlorine gas. However, other than fire departments, few other local emergency organizations would normally have such equipment. This lack of equipment can occasion problems, as witnessed in a recent chlorine gas incident in Arkansas, where the majority of 14 persons who received hospital treatment were railroad workers or law enforcement officers. It is also uncertain whether the dosimeters necessary for monitoring exposure to nuclear radiation would be locally available. Given long enough time between warning and actual impact, it is conceivable that the necessary protective equipment for some emergency personnel could be brought in from outside the community, but this assumes questionable integration of known stockpiles, as well as swift communication and rapid transportation before impact. The more likely possibility is that local communities would be on their own during impact for both hazards.[103]

3. <u>Mobilization of Emergency Personnel and Resources</u>

Assuming some warning, both local and more distant organizations would start to learn about the incident before or during impact. Research on their involvement in chemical disasters generally suggests that mobilization would not proceed smoothly. Thus, one study which examined some chlorine gas incidents reports:

> The process of seeking outside aid and expertise in chemical incidents is usually uncoordinated. Sometimes there is a delay before some organization decides to take the initiative. More often, various local groups independently request outside help and are unaware that others are doing the same. In many instances, more outside assistance is requested than is necessary. Eventually, this contributes to the typical post-impact convergence problem in disasters. When seeking aid and information, local officials do not turn to any particular extracommunity organization

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[103]Clearly, the greater technical capability and knowledge of the hazard threats is likely to reside at regional and national levels. For example, how many local agencies might be aware that spraying water on the threaded connections of a tank car leaking chlorine will cause water to react with the chlorine, forming an acid that will corrode the steel and worsen the leak? Such information is available in manuals, but as indicated earlier, there is an initial difficulty in identifying the nature of the threat and what to do about it. However, witnesses from five agencies testifying before the NTSB:

> ... indicated that reliance on technical manuals, placards, computer printouts, and waybills did not fulfill their informational needs. They stated that all too often placards located on hazardous material tank cars were destroyed, the knowledge of the train crew was limited as to the exact placement to tank cars and the materials carried, and in immediate emergency conditions, there was not adequate time to search for waybills and cross-reference materials with an emergency manual to determine general emergency actions.

See <u>Safety Effectiveness Evaluation</u>, <u>op</u>. <u>cit</u>., p. 11.

> or source of possible assistance. There are, however, a few states that have a state civil defense agency or equivalent group whose response capabilities to chemical emergencies are well known to local officials. Also, knowledge of CHEMTREC is fairly widespread although far from universal.[104]

There might also be a difference in the two types of disasters on how quickly and effectively more distant relevant organizations would be notified of an incident. There is a growing local familiarity, or at least sensitivity, to acute chemical hazards among all but the smallest fire departments. Many, but not all, five agencies are aware of the CHEMTREC toll-free emergency number.[105] Although calls to CHEMTREC are usually for the purpose of obtaining information about how to deal with the emergency, a call will usually alert other outside organizations. On the other hand, there is much less familiarity at local levels with nuclear threats and possible sources of information. It could be anticipated that getting word out of a nuclear transportation incident might be slower. There is no one number to call

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[104] See Unscheduled Events, op. cit., p. 7.

[105] CHEMTREC, the Chemical Transportation Emergency Center in Washington, D.C., is designed to provide immediate information to carriers and public safety officials facing a chemical transportation emergency. The Center was officially reorganized in March 1980 as the central emergency response service for dealing with hazardous material transportation incidents, and works with the U.S. Coast Guard's National Response Center in this endeavor. In nine years, the Center had received more than 13,300 calls about transportation emergencies. When CHEMTREC receives a call, it works from a file of more than 35,000 products to provide immediate information to those at the scene of the emergency. Drawing on an equally comprehensive file of telephone numbers, CHEMTREC then notifies the shipper of the transportation-accident. See Transporting Chemicals Safely, 1980, pp. 17, 19. (Need complete citation)

such as CHEMTREC, nor do most transportation emergency manuals cover nuclear material. Thus, instructions for railroad personnel stress the need to inform immediately the shipper of the nuclear material involved. However, railroad emergency manuals typically list no special numbers to call. They merely give regular NRC telephone numbers which should be called, depending on the region in which the train accident occurs.

4. Search and Rescue

5. Care of Victims and Survivors

The only search and rescue actions that might be involved in these disasters would be of a very limited nature and relate to the transportation accident itself. In the majority of cases, those searched for would be only a handful of train crew members. Local emergency personnel and resources generally would be sufficient to meet the need. Compared with most other disasters, the function of search and rescue in the kinds of transportation accidents being considered in this chapter, is almost always insignificant, and, if required, is largely a local function. It should be noted that there would be different protective action requirements for search and rescue personnel in these two cases.

With respect to the care of victims and survivors, evacuation in both disasters would be for relatively short periods of time, and it is almost certain that all evacuees would be able to return to their homes. Usually there would be no need of more than overnight sheltering, no problem of replacing lost clothing or personal property, and no problem of shortage or absence of food. Extremely isolated cases of evacuees who might need food clothing, or long-term shelters could easily be handled by the ordinary public and private welfare and social service agencies.

The only problem with respect to this function might be in connection with medical care. Chlorine, as indicated, can have delayed effects; but anyone affected would normally have been aware of being exposed. Treatment is fairly well known, and would be generally available from local medical personnel.[106] Exposure to high-level nuclear waste or spent fuel would not be as readily recognized. Health effects would be different for the exposure to chlorine gas versus nuclear radiation. Any mental health consequences from either hazard would not be immediate but might become an issue during the rescue and rehabilitation and recovery phases of the disasters.

Impact--Conclusions

1. Protective action and evacuation would continue during impact, with differences rather than similarities between the two hazards perhaps becoming sharper. For example, chlorine would become more readily detectable to the senses but its threat could spread to a much wider area. Evacuation would continue to be the primary protective action possible for the population as a whole.

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[106] This is true in principle, but less so in fact. There are often two problems. Until the chemical is identified, medical personnel have only symptoms to deal with and they are not self explanatory. Also, even when a dangerous chemical is identified on the accident scene or by emergency personnel, such information is not always passed on to hospital or medical personnel. See Unscheduled Events, op. cit.

2. With identification and knowledge of the threat, additional protective measures specific to each hazard could be taken by emergency personnel in the immediate vicinty of the accident site. This would be possible only if the required resources (e.g., gas masks for chlorine and dosimeters for nuclear radiation) were available locally. The local availability of these resources is uncertain.

3. The pattern of similarity and difference across the two hazards of local mobilization of emergency personnel and resources, noted earlier, would continue. The mobilization of state and national levels of response for chlorine disasters might be more rapid because of greater local familiarity with these outside resources and their availability. The outside resources, themselves, are different for chemical and nuclear hazards.

4. Search and rescue would almost always be an insignificant problem for both hazards, and if required, would be an exclusively local function. The performance of the function would be similar except for the different protective actions required of search and rescue personnel.

5. The care of evacuees would be highly similar for both hazards but medical care requirements would be largely different. The performance of this function would be local for both hazards during this time phase.

Isolation

The concept is only meaningful for these two hazards in the sense that impact areas would be isolated through evacuation of threatened populations. Local emergency and other resources and personnel would be immediately mobilized to accomplish evacuation as well as the other post-impact functions.

1. Protective Action

Protective action (principally evacuation) continues to be necessary for varying periods of time and distance for both hazards. In the instance of chlorine, although normally there will be a degree of dispersion and dilution of the gas, it might take several hours for the concentration to drop below a nondangerous level. The threat through time might extend for miles from the original point of the accident. We have already indicated earlier how far a chlorine gas cloud might drift. This highlights the fact that the scope of the impact might be diffuse by our interpretation of the concept. In certain situations there would be the temporary need not only to protect the first people to appear on the scene and the nearby population, but people who might be located at a considerable distance from the accident site. In contrast, the danger from a nuclear material transportation accident would likely remain largely limited to the immediate accident site. Far fewer people would likely be evacuated but, because of lingering radiation, the affected area would probably have to be isolated for a considerably longer period of time than for chlorine accidents.

2. Search and Rescue

3. Care of Victims and Survivors

The comments made earlier about these functions would apply to this later time period. Search and rescue is a very unlikely activity after initial impact; to the extent it is undertaken about the only problem might be the direct exposure, as indicated earlier, of both the rescuers and rescued to the chlorine or nuclear threat. To the extent there might be any victims, different specialized knowledge and personnel would be necessary for medical treatment.

4. <u>Damage and Needs Assessment and Inventory of Available Resources</u>

The assessment problem would relate to determining (1) emergency service requirements of evacuees; (2) medical care requirements of victims; (3) requirements for containing and controlling the chemical or radiation release; and (4) repair requirements related to the transportation accidents themselves. The assessment process would be somewhat similar for both hazards, with differences dictated by the previously discussed distinct characteristics of each one. Most notable of these differences would be the special requirements of monitoring radiation levels and identifying degrees of radiation exposure. Local performance of this function would dominate during the isolation phase.

5. <u>Damage Control</u>

This function is very important in both kinds of disasters. In the instance of chlorine there has to be an effort to stabilize the threat, that is, either to prevent a leak of the tank car, or if a leak has started, to minimize it or shut it off. In general, this has to be done by local groups. By the time outside groups would arrive, normally either gas would have leaked and dissipated, or the leak would not have occurred. Of course, outsiders might be arriving because of the news of the train accident, and have no knowledge of other associated threats, but, unless their movement was extremely fast, in most cases the chlorine would no longer be a danger by the time they arrived. However, outsiders might be important, as noted later, in assuring resumption of safe operations.

This contrasts sharply with the damage control situation in the case of nuclear material transportation accidents. We have already noted that if railroad personnel (and other local emergency personnel) were aware that the threat might be of a nuclear nature, it is very unlikely that any damage control measures would be initiated except for the most urgently needed fire fighting. It is unlikely, therefore, that in nuclear disasters this function would be carried out during the isolation period; it would likely await the arrival of technical assistance from state and particularly national agencies at the disaster site.

6. Mobilization of Emergency Personnel and Resources

7. Mobilization of Other Human and Material Resources

Function No. 6 would have been initiated earlier and continued, while the more improvised response reflected in function no. 7 would begin now. The emphasis during this time phase remains on the local level, with a continuing pattern of similarities and differences dictated by the impact characteristics of each hazard. An uncertain state but notable national level mobilization would be fully underway but its impact on the scene would not yet be felt. As stated earlier, the technical personnel and resources involved in this outside mobilization would be different for the two hazards. In the case of chlorine, the mobilization would be the nationwide mutual aid network represented by the CHLOREP program. In the case of nuclear hazards, it would involve federal agencies represented in the Interagency Radiological Assistance Plan and probably the FEMA. As noted earlier, the effectiveness of plans related to these programs is uncertain.

Isolation--Conclusions

1. Previously noted similarities and differences related to protective action (including evacuation) also pertain to this time phase. The necessity of protective action is importantly tied to scope of impact for chlorine transportation accidents and to duration of impact for nuclear transportation accidents.

2. Comments made earlier about search and rescue and care of victims and survivors would apply to this time-phase.

3. Damage and needs assessment and inventory of available resources would be somewhat similar for both hazards, with differences dictated by the previously discussed distinct characteristics of each one. Most notable of these differences would be the special requirements of monitoring radiation levels and identifying degrees of radiation exposure. Local performance of this function would dominate during the isolation phase.

4. The initial damage control problem would involve attempts to minimize or stop the chemical or radiation release at its source. It is difficult to judge how similar or different the activities required to accomplish this task would be, but it is likely that their locus of performance would not be the same for the two hazards. Initial damage control operations would be in local hands for chlorine hazards. However, it is expected that for nuclear transportation accidents, only minimal damage control efforts would be initiated prior to the arrival of technical assistance from state and, particularly, national levels.

5. The mobilization of emergency and other personnel and resources exhibits a pattern of similarities and differences at the local level--one dictated by the impact characteristics of each hazard. Technical personnel and resources involved in the mobilization of outside assistance (not yet on the scene) would be appropriately dissimilar for the two hazards.

Rescue and Rehabilitation

1. Protective Action

2. Search and Rescue

3. Care of Victims and Survivors

4. Damage and Needs Assessment and Inventory of Available Resources

Earlier comments about the performance of these functions do not require any major amendment for this time phase. Emphasis on local performance of these functions continues, but national level involvement in providing or financing emergency services for evacuees and victims would now be relevant and similar for both hazards. National level involvement in damage and needs assessment would also be likely for both hazards but, as noted earlier, some of the technical requirements for assessment clearly would be different.

5. Damage Control

Damage control--one heavily dependent on experts from outside a local area--would be a major task during this time period for both hazards. In the instance of chlorine, a CHLOREP team would probably arrive. They should have the technical expertise and equipment to minimize or stop the release if it still continued. A problem might be the convergence of too many officials and groups, and a lack of coordination among them.[107]

In the case of a nuclear transportation incident, there might be other problems in attempting to control damage. One report that noted Federal authority under IRAP is limited to assistance to responsible authority. Exception is taken only when the IRAP team is "first-on-the-scene." Even then, their control of the situation is intended to be yielded to responsible authority once that authority arrives at the scene. Most frequently such authority is assumed in the report to rest with state officials.[108] That seems to be a rather optimistic assumption since local officials often assume that they have responsibility and control over the disaster site. Possibilities for misunderstandings or conflict are obvious.

In a nuclear incident there would also be the unique problem of protecting the damage control workers from the radiation hazards. Railroad officials have questioned how easy this would be, suggesting that "remote equipment would be required to erect a shield around the fuel elements or to place them in a shielded box, or to repackage them. This could be a most difficult task owing to the extremely high levels of radiation involved."[109]

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[107] See Cashman, op. cit.

[108] See Darr, op. cit.

[109] See U.S. Congress, Senate, Committee on Commerce, Science, and Technology, Hearings on Nuclear Waste Transportation Safety Act of 1979, op. cit.

One of the most important damage control activities relates to the disposal of contaminated material. In the case of chlorine accidents, runoff water from fire fighting or dilution efforts may be contaminated. Normally, neutralizing such contamination would require the assistance of the state Environmental Protection Agency (EPA), if not the federal EPA or U.S. Coast Guard. A parallel but different problem would exist with the clean-up necessary if there had been radiation contamination. Normally a carrier is responsible for clean-up after an accident. However, railroads are "not expected to have any expertise in nuclear hazard evaluation. For that reason, and because of the publics apprehensiveness, radiological assistance is available from DOE and from both state and local health agencies. This assistance consists of advice and emergency action essential for the control of immediate hazards to health and safety of the public. Responsibility for postemergency authority is assumed by the carrier or the responsible local authority."[110] In any event, the technology needed for cleanup of chlorine or other chemical contamination would differ significantly from the radiation detection and decontamination techniques for nuclear transportation hazards.

[110]U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 37.

Overall, we conclude that the performance of damage control would continue to be largely dissimilar for these two hazards during the rescue and rehabilitation phase. Both different skills and equipment would be required and their sources would be different--the private sector for chlorine transportation accidents, and the public sector for nuclear transportation accidents. In short, although the objectives are quite similar for both--i.e., to remove dangerous pollutants from the biosphere--the techniques, the personnel, and the administrative responsibilities would be quite different.

6. Restoration of Essential Public Services

Unless the transportation accident blocked a very crucial railroad track, it is difficult to visualize the need to restore public services or lifelines that would have been disrupted. Even if some transportation services, such as buses or subways, had been temporarily suspended, they could be quickly reestablished once the chlorine gas had dissipated. The continued presence of radiation danger as a result of a nuclear transportation activity would require that a contaminated area be placed off limits until the threat was neutralized; but since in the posited scenario the affected area would probably not be larger than about a city block, the probability that any public service would be disrupted, seems very small. Restoration of the railway track itself would follow very standardized procedures with the use of company crews and equipment which are deployed on a very regular basis. However, if there were a serious release of nuclear materials, it seems highly probable that track repair would be far from being a routine task.

7. Public Information

Public information would be especially important in the kinds of disasters being discussed in this chapter. There is reason to believe that many people, including public officials, do not have adequate information about both chemical hazards and high-level nuclear wastes and spent fuel. Both subject areas are the focus of widespread and intense controversies, with interest and ideological groups on both sides of the controversy flooding the public with many questionable assertions and far from impartial statements. The problem is probably more acute in the nuclear field, but with the widespread publicity given to the Love Canal episode and related incidents, the dangerous chemicals area is also coming to the fore as a very controversial topic. With this as background, a transportation accident involving chlorine or dangerous nuclear material, would both generate requests for public information and a responsibility for authorities to provide it.

Related studies on public information in other types of disaster suggest this function would not be fulfilled very well in chlorine or hazardous nuclear material transportation disasters. One study of chemical disasters concluded that: "Public information about acute chemical disasters is usually poorly handled in most communities."[111] The problem is partly attributed to the fact that an emergency operations center is seldom established in chemical disasters. The study also noted that frequently

[111] See Unscheduled Events, op. cit., p. 7.

no organization takes responsibility for the task. This in part also stems from the fact that most emergency organizations do not believe they have much competence in talking about chemicals. The study additionally noted that:

> If sources of public information are present at the on-site command post, many officials may provide partial information. The result is that usually incomplete and often incorrect information about the incident is issued and circulated at the time of the emergency. Because mass media personnel will press for news items, efforts to limit any release of information will not be successful.[112]

The public information in connection with the Three Mile Island power plant accident suggests that some of the same problems and issues might be involved in nuclear transportation accidents. Both spokespersons for emergency organizations and journalists had considerable difficulty in understanding and communicating accurately about the nuclear threat. Although the kind of transportation accident we are considering in this chapter would be on a smaller scale than a potential reactor emergency, there is reason to believe that there would be substantial difficulties in carrying out the public information function.

There are clear similarities in the dissemination of public information in all disasters. However, the knowledge required, the sources of the knowledge, and explanations of the nature of the threat would differ somewhat in the two kinds of transportation disasters we are considering. The matter would also differ somewhat depending on whether the public information

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[112] Ibid., p. 7.

was for threatened local residents, populations farther away who might be endangered (which might be the case in a chlorine disaster), or simply the public at large.

8. Maintenance of Political Order

Except for the cordoning off of the impact area, setting up roadblocks, and otherwise regulating traffic, neither of the two disasters should create much of a problem in maintaining the political order. The function is generally similar for both hazards, would be handled primarily at the local level with perhaps some assistance from the state. Even if a massive evacuation were necessary, and the military was needed to assist, it would still be the National Guard and not federal troops. At a broader level, if there had not been effective prior planning, there would likely be lack of coordination within and between the public sector and the private sector. However, this is a problem in disasters generally, and there does not appear to be anything special or unique in this matter in either chlorine or hazardous nuclear material transportation disasters.

9. Organization of Emergency Personnel and Resources

10. Organization of Other Human and Material Resources

The discussion of earlier emergency response functions illustrates once again that the organization and management of human and material resources is a functional imperative for effective disaster response. This case comparison makes clear that local emergency requirements for technical resources and the predominantly extra-local location of these resources create management problems of linking local, and particularly national, levels of response. These management problems have similar elements, evidenced in part by selected similarities in the performance of earlier emergency response functions. At the same time, the expression of these management problems varies in technical detail and public-private sector emphases across the two hazards. For both hazards, there is an abundance of planning to ensure an effective response of extra-local resources to local emergency needs. At the same time experience suggests that the relationship between disaster planning and reality is imperfect at best. Those agencies involved in preparedness for one or both of these hazards should work to ensure that their programs and operations are carefully interlinked.

Rescue and Rehabilitation--Conclusions

1. Earlier comments about protective action, search and rescue, care of victims and survivors, damage and needs assessment, and inventory of available resources do not require any major amendment for this time phase. National level involvement for both hazards would now be reflected in (1) providing or financing emergency services for evacuees and victims, and (2) damage and needs assessment. The former would be very similar for both hazards while the technical requirements of the latter clearly would be different.

2. The performance of damage control would continue to be largely dissimilar for these two hazards during the rescue and rehabilitation phase, with important but clearly different national level influences on the technical performance of this function.

3. It is very unlikely that essential public services would be disrupted by either hazard. Thus, it is concluded that restoration of essential public services is irrelevant to this case comparison.

4. There are clear similarities in the dissemination of public information in all disasters. However, the knowledge required, the sources of the knowledge, and the explanation of the nature of the threat would differ somewhat for these two hazards.

5. The maintenance of political order is generally similar for both hazards and would be handled primarily at the local level, with perhaps some assistance from the state. Even if an evacuation were massive, and the military was needed to assist, the military assistance would involve the National Guard rather than the use of regular force federal troups.

6. Management problems related to the organization of emergency and other human and material resources have similar elements, evidenced in part by selected similarities in the performance of earlier emergency functions. At the same time, the expression of these management problems varies in technical detail as well as public-private sector emphasis for the two hazards.

Recovery

1. <u>Reconstruction of Physical Structures and Infrastructures</u>
2. <u>Reestablishment of Production, Distribution, and Consumption Activities</u>
3. <u>Resumption of Other Basic Institutional Processes</u>

Of the four functions being discussed in this report under the recovery time phase, only one of them would seem relevant to the kinds of transportation disasters we have posited. This would be the determination of responsibility and legal liability for the event. Reconstruction of public and private physical structures and lifeline systems appears irrelevant in transportation accidents where the only physical damage is likely to be to a few railroad cars and some rail tracks. Even if there is an explosion, which is possible in a chlorine incident, some flying fragments may produce slight damage to buildings and property up to several thousand feet from the transportation accident site, but such damage as a whole would likely be miniscule.

There would be no need to reestablish production, distribution, and consumption activities because these activities would not have been significantly disrupted by the emergency or disaster event. While a chlorine incident might require the evacuation of the population over a number of miles, the activities that would be suspended would, under most circumstances, last for only a period of hours. Even in the Mississauga, Canada, incident where the area was evacuated for about five days, all activities were reestablished with very little difficulty, as if the time suspension had been simply an extra long weekend. The same would be true of other institutional processes. The only conceivable way in which any institutional process would be seriously disrupted and need to be restored in the recovery period, would be in the unlikely event that there were extremely large number of casualties resulting from a chlorine accident.

4. Determination of Responsibility or Legal Liability for the Event

There are two separate processes involved in this function. One is blame assignment, which may eventually translate into political action. The other is the legal liability which would manifest itself in the civil and criminal justice system. However, what would actually happen in the case of the two disasters we are discussing would require informed speculation in the absence of adequate empirical evidence. It is also extremely difficult to couch whole functions in terms of local, state, or national levels because we are talking of a broad range of possible activities and actions. These might include class-action law suits; the reinforcement of anti-nuclear groups in their beliefs about the irresponsibility of the government and the nuclear and chemical industries; attempts to defeat in elections public officials who are viewed as having some direct or indirect responsibility for a disaster; or attempts to have laws passed to prohibit certain kinds of transportation shipments.

Only a few illustrative matters can be discussed since what would be involved is not an act of nature such as a tornado, but of some form of human failure. Thus it is probable that the issue of blame assignment would arise in both cases.[113] That probability is reinforced, of course, by the controversial social climate surrounding hazardous chemicals or dangerous nuclear material. However, the whole process of public assignment of blame is little understood, and needs considerable research.

[113] See T. E. Drabek and E. L. Quarantelli, "Scapegoats, Villains and Disasters," Transaction, Vol. 4 (March 1967), pp. 12-17.

The private sector as producers, shippers, or carriers would be involved in the transportation disasters. For obvious reasons, these private sector companies would probably undertake major efforts to avoid either becoming the object of blame or the focus of legal action. While the insurance provisions discussed earlier would presumably be operative in the aftermath of the transportation disasters, they would not prevent private companies from becoming the focus of blame or action.

Although the public sector might be able to protect itself from legal attack, it would not be immune to being blamed or invulnerable to political sanctions. In what ways, and to what extent, public officials and agencies are influenced in their disaster behavior by concern over public or political attack, has never been systematically studied. Impressionistic observations suggest such matters are very important, but solid research evidence is lacking. However, it is difficult to believe a major transportation disaster involving high-level nuclear wastes or spent fuel, would not acquire postimpact political implications. Antinuclear interest groups would almost certainly seize upon such a disaster as symbolic of the dangers involved with nuclear power. In fact, the symbolism, as in the Three Mile Island nuclear power plant accident, might be more important than any actual damage.

The determination of responsibility and legal liability for the event would also be related to the reporting requirements regarding hazardous materials transportation accidents and disasters. Since 1971, the DOT has required all carriers to report certain hazardous materials incidents.

Basically a report is required if anyone is killed, requires hospitalization, or if property damage exceeds a certain dollar amount. Reports are also required if fire, breakage, spillage, or suspected radioactive contamination occurs involving shipment of radioactive material. Thus, reporting requirements are much more stringent for nuclear incidents than dangerous chemicals. It is conceivable that the chemical transportation disaster posited for purposes of this chapter might not formally be reported if it actually occurred, whereas the nuclear disaster proposed in our scenario would almost certainly be reported. The reports are required to be submitted to the DOT, within 15 days after the incident. But in view of the fact that they might be used to determing responsibility and legal liability, these reports tend to omit critical details and therefore have limited use for research purposes.

Recovery--Conclusions

1. It is very unlikely that reconstruction of physical structures and infrastructures, reestablishment of production, distribution, and consumption activities, and resumption of other basic institutional processes would be relevant functions for either of these hazards.

2. While the specific issues involved would likely be different, the determination of responsibility or legal liability for the respective events suggest strikingly similar processes.

GENERAL IMPLICATIONS

It is possible to conclude from the preceding description and analyses that the unknowns in this functional comparison between disasters involving hazardous chemicals and nuclear materials are far greater than the knowns. It is also clear that many of the conclusions and implications rest on incomplete, weak, or dubious data and evidence. The first two sections of the chapter deliberately detailed the problems in approaching a discussion of transportation disasters involving hazardous chemicals and dangerous nuclear material. Without an appreciation of the points made in those sections, it would be difficult to interpret any of the observations or conclusions we made in the comparative analysis in the third section of the chapter. Despite the deficiencies in the research and the data base, however, it was possible to discern some major and minor themes that were summarized in the previous section.

Much of what we have found in our comparative case analysis of the two disasters examined stems from four factors. These factors also distinguish this case comparison from the other three cases covered in this report. First, both disasters analyzed in this chapter stem from human actions or accidents; neither one is caused by a natural disaster agent. Second, transportation accidents are relatively limited in destructive power, especially as to the property damage they can produce. Third, both the public and private sector are intricately involved in all aspects, from the disaster preparedness phase to the recovery period. Finally, dangerous chemicals such as chlorine and hazardous nuclear materials, are inherently different disaster agents, both intrinsically and in the ways they are transported. Given all this, it should not be surprising that we found that the functions in both disasters were more different than alike, and that this case comparison also differed substantially from the other three case comparisons, especially at state and national levels.

Certain general implications can be drawn from the preceding analysis. Thus, policy issues regarding many matters with respect to dangerous chemicals and hazardous nuclear material have not been well conceptualized. The FEMA and other emergency relevant organizations ought to reexamine the adequacy of current policies on this subject. For example, should FEMA be involved in the preparations for and responses to chemical disasters as it is for other kinds of mass emergencies? Planning for the two kinds of disasters discussed is often fragmented, and occurs at different public and private organizational levels. Integration of planning efforts might be possible in some areas, but as a whole, both disasters have certain distinctive attributes which require separate attention. In particular, the whole public-private sector relationship with respect to both chemical and nuclear disasters needs closer examination. Operational responses to both kinds of disasters suggest that much will be handled in actual incidents on an improvised basis. It is important that there be recognition for the need to allow for emergent activities to handle contingencies and situational factors. General principles can be developed, but implementation of specific details can only be done on the basis of the actual situation rather than trying to follow some model plan.

At the most general level, there is one disturbing implication about much of the thinking and writing about the kinds of transportation disasters posited. In particular, a point of view prevails about possible hazardous nuclear materials transportation disasters. It is exemplified in the quotations in the following paragraph.

Running through much of the literature on nuclear hazards is the idea that the possibility and probability of a transportation disaster is all but nonexistent. Thus we are told that "the consequences of a 'worst case' urban area rail accident involving a spent fuel shipment were estimated..." and the impact "of rail shipments of fuel cycle materials was found to be insignficant."[114] Another study of the transport of radioactive materials originating from the nuclear fuel cycle reports that "The detailed study... has clearly demonstrated that the potential environmental impacts are presently, and will remain in the future, small if not negligible."[115] Still another research abstract reports that a realistic assessment of a nuclear cask during a hypothetical railroad accident, shows that "the accident events which must occur before a release of RAM, other than gases, is possible are in themselves incredible, and... the biological effects of a release of fission gases will in all likelihood be nil."[116]

[114]See D. Smith and J. M. Taylor, Analysis of the Radiological Risks of Transporting Spent Fuel and Radioactive Wastes by Truck and by Ordinary and Special Trains (Albuquerque, New Mexico: Sandia Laboratories, 1978), p. 10.

[115]See Y. Sousselier, Environmental Impact of Waste Management and Transport of Radioactive Materials Originating from the Nuclear Fuel Cycle (Richland, Washington: Battelle Pacific Northwest Laboratories, 1979).

[116]See R. T. Anderson, Realistic Assessment of Nuclear Cask During a Hypothetical Railroad Accident (Barnwell, South Carolina: Allied General Nuclear Services, 1978).

The major justification of such positions is that the technical safeguards and regulatory requirements will prevent serious problems from occurring. Thus still another report states that:

> The packaging standards for radioactive material are such that the danger or threat from radiation should be a minimal worry in any transportation emergency. The likelihood of a release of any radioactive material in a transportation accident is very small and the probability of the release of hazardous quantities, so small as to be considered negligible. Emergency crews should be instructed to disregard radioactive material signs in the initial phase of every traffic accident and to deal with the emergency as it appears, with no special concerns for the possibility of the presence of radioactive material, i.e., taking only normal precautions such as avoiding smoke inhalation and not entering the immediate area or handling cargo unnecessarily.[117]

Or in the words of the DOE: "The risk of public catastrophe has been eliminated by strict standards, engineering design safety, and operational care. Whatever the consequences of an accident are, the public hazard will be manageable, and the nuclear effects will be small compared to the non-nuclear effects."[118] A manager of a nuclear transportation technology testified before a Congressional committee that: "the tests we have conducted with spent-fuel shipping casks to date shows that there simply is not an accident within the realms of possibility that is going to seriously threaten that cask."[119]

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[117]See R. F. Barker, Regulatory and Other Responsibilities as Related to Transportation Accidents (Washington, D.C.: Nuclear Regulatory Commission, Office of Standards Development, 1977), p. 7.

[118]See U.S. Department of Energy, Everything You Always Wanted to Know About Shipping High Level Nuclear Wastes, op. cit., p. 51.

[119]See U.S. Congress, Committee on Commerce, Science, and Technology, Hearings on Nuclear Waste Transportation Safety Act of 1979, op. cit., p. 154.

These and similar kinds of statements might be accepted at face value, except that other knowledgeable experts dispute many of these assertions, and disaster research generally does not support the idea that technology or regulations will prevent disasters. Thus a railway official in the same Congressional committee hearing cited above, wrote a letter to the effect that:

> NRC has no adequate appreciation or understanding of the risks of operating in the railroad environment or of the tremendous forces exerted by collisions or the lengthy fires which can occur. NRC's cask specifications reflect its lack of transportation expertise. To cite just one example, NRC requires that a cask be able to sustain exposure to fire at a temperature of 1,475 degrees for 30 minutes. 10 C.R.F. Part 71, Appendix B (1979). This is oblivious to the facts that trains and the terrain in which they move contain ample combustible materials which allow railroad fires to burn for days at high temperatures. Extensive fires have been known to occur even in railroad tunnels which have been turned into ovens by intense heat driving local firefighters from the accident. There may be limitations in the extent to which shielded casks can be made safer. However, the public can be safeguarded by controlling the transportation environment, which the NRC does not understand, through special handling of casks containing nuclear materials. If the NRC is given primary responsibility for regulating and certifying the safety of transportation casks, DOT's primary responsibility for safety, regulation, and logistical aspects of the transportation of nuclear waste and spent fuel would exist in name only, and it is unlikely that any significant safety improvements would occur. We strongly oppose the present wording of proposed Section 115(a) which would give DOT a back seat role on transportation cask safety.[120]

[120] Ibid., p. 213 (Letter from Union Pacific Railroad Company official.)

Disaster research is replete with studies of how complete dependence on technological safeguards has usually proved fallacious and how rules and regulations routinely fail to be followed or are ignored and violated. Even granting that more care may be taken in the transport of hazardous nuclear material than might be taken in other areas, there is little in the empirical record to suggest such uncritical reliance on technology and rules. Obviously improvements in safer technology are to be sought, and stringent rules and regulations should continue to be demanded, but it would be dangerous to stop at that point.

A Congressional committee report recently recognized part of the problem. It notes that:

> The Department of Transportation's emphasis in the field of hazardous materials has been focused on the prevention of accidents by means of regulatory and enforcement measures. While such measures have not received too great an amount of attention, additional consideration needs to be given by the Department to the area of accident response.[121]

This suggestion is a partial move in the right direction. It assumes that transportation accidents will occur, and that there is a need to develop preparedness planning and organizational responses to the consequences.

A further helpful step would be to recognize that the danger lies primarily in the transportation process and not mainly in the products being shipped. Or, as one NTSB report said: "There is no uniform framework for analyzing the problems of dangerous goods transportation, and the

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present regulations focus on the inherent nature of the commodities rather than the risks created by their movement."[122] A focus on the transportation process would force more attention on the need for organizing disaster preparedness and response, which is essentially a social rather than a technical issue.[123]

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[122]See National Transportation Safety Board, Risk Concepts in Dangerous Goods Transportation Regulations--Special Study (Washington, D.C. NTSB, 1971), p.____.

[123]There is essentially a recognition of this in National Transportation Safety Board, Special Study--Railroad Emergency Procedures (Washington, D.C.: NTSB, 1980). See also M. Lindell and R. W. Perry, "Evaluation Criteria for Emergency Response Plans in Radiological Transportation," Journal of Hazardous Materials, Vol. 3 (June 1980), pp. 335-348, which points out that it is possible to take research findings from social studies in the natural hazard area, and to apply them to the problem of emergency planning for transportation accidents involving potential releases of nuclear materials.