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Issues in Emergency Preparedness for Radiological Transporation Accidents

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ISSUES IN EMERGENCY PREPAREDNESS FOR RADIOLOGICAL TRANSPORTATION ACCIDENTS

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INTRODUCTION

As of 1980, there were 75 nuclear power plants in existence in the United States. Several million packages of military and civilian radioactive materials travel over the nation's transportation routes every year. The volume of radiological shipments is growing rapidly. One study predicted that shipment volumes would increase by ten-fold between 1975 and 1985.[1] The safety record of the nuclear industry is good, but radiological accidents do happen. Clearly, their chances of happening are increasing over time.

Emergency preparedness for radiological accidents differs from normal emergency preparedness in a number of respects: it involves evaluating and reacting to an unseen hazard in timely fashion and facilitating rapid communications between several layers of government, including the federal government. Also, as will be seen, speed of response is of greater relevance to different classes of decisions concerning radiological accidents than to decisions concerning typical non-radiological industrial or highway accidents. Nuclear accidents can occur at specific sites (reactor sites, waste disposal sites, defense plants, etc.), or at any point along transportation routes. In this discussion, we concentrate on preparedness for transportation accidents, since site-specific planning is relatively more developed and is inherently more tractable, being confined to a manageable number of locations.

The next section outlines the major issues and decision areas regarding preparedness for radiological emergencies. The final section draws together the conclusions of that discussion.

THE MAJOR ISSUES IN RADIOLOGICAL EMERGENCY PREPAREDNESS

The issues which have emerged in recent years on this topic arise in connection with the emergency response decisions to be made by

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1. U.S. Nuclear Regulatory Commission, Final Environmental Statement on the Transportation of Radioactive Material By Air and Other Modes, to F.R. 23768, NUREG-0170 (December 1977) [hereinafter FINAL ENVIRONMENTAL STATEMENT].

local governments, the role of federal, state and local governments in accident response, and the methodological concerns in emergency response planning. We list and then discuss these issues in that sequence.

a) *Decision-related Issues*
- Pre-notification: at the state and local level, who should be informed of the contents of radioactive shipments, and with how much lead time?
- What scale of emergency should be planned for? Does the likelihood (which is remote) of large-scale catastrophes affect the desired degree of preparedness for them?
- At the local level, who should be charged with emergency response?
- At the local level, who is responsible for the potential evacuation decision?
- How do we develop criteria for determining the desired speed of emergency response? In what respects is time most essential?
- What kinds of training and equipment are required for reresponse teams?

b) *Issues Related to Intergovernmental Relationships*
- What are the merits of relying on regional federal response teams instead of local government units to handle radiological accidents?
- What sort of plans should be and are being undertaken by state and local government and what are their costs?

c) *Methodological Issues*
- Is benefit-cost analysis applicable to deciding the design and scale of emergency response programs?
- Do there exist clear criteria regarding adequate levels of emergency preparedness?

a). Decision Related Issues

Pre-notification has been a contentious issue, pitting the states against the Nuclear Regulatory Commission (NRC) and the U.S. Department of Transportation (DOT). A number of states have promulgated regulations requiring advance notification to the state of each radioactive shipment passing through it. In many instances, these regulations require that the governor be so notified. Critics of such regulations have pointed out, however, that a governor is not necessarily the most appropriate person in the state to notify.[2] Last-minute changes in schedules by drivers and shippers pose an operational problem in pre-notification. These changes make ensuring the accu-

2. State Planning Council on Radioactive Waste Management, Transportation Workshop, Report, 19 (Washington, D.C. 1981).

racy and timeliness of notification difficult. Further, federal officials are concerned that dissemination of information on these shipments may facilitate sabotage attempts.

We would like to suggest that the debate concerning pre-notification has been on the wrong track. If the premise is accepted that pre-notification is required primarily for emergency preparedness purposes, then the role of the pre-notification information becomes clearer: it is to assist the emergency response team in acting more effectively. Following this line of reasoning, a state's governor need not receive routine pre-notification (although he would want to retain the right to request statistical tabulations or other occasional data on the shipments). In fact, no one need receive the information routinely–for in most instances it would not be required for decisions. Instead, what is required is *access:* the ability to identify the contents of a shipment immediately in the event that it is involved in an accident. For this purpose, an accessible system of electronic information storage would be more effective than regular written communications. For example, a terminal operated only by designated individuals could be installed in the state police headquarters. After a patrolman arrives at the scene of an accident and notices the nuclear placard, he would radio headquarters for a description of the contents of a given truck (identified by location, time, license number, and other obtainable information). The terminal operator then would request a description of shipment contents from the national preparedness information system. This information should be available immediately, and would be relayed to the patrolman. Other modalities could be visualized, but this example illustrates how an emergency-oriented notification system could operate. Most of the issues discussed in this article are of an institutional nature, but the pre-notification issue is one which may be, in essence, a technological problem of information retrieval, storage, and timely transmission. A system for providing access to shipment information may be worth investigating as a potential contribution to resolving the state-federal conflicts over pre-notification rules.

The problems caused by the lack of information on shipments are amply illustrated by the case of a rail accident in North Carolina. In March of 1977, a train carrying uranium hexafluoride and other hazardous materials derailed near Rockingham, and the response to that accident has become a textbook case of inadequate emergency preparedness, primarily owing to ineffective communication. According to the U.S. Government Accounting Office (GAO), "at least 17 Federal, State, local, and private agencies responded to the accident. However, no one assumed control until a state radiological team arrived. Even then, a lack of coordination and serious communication problems existed."[3]

The National Transportation Safety Board (NTSB) conducted a special investigation of that incident. As matters turned out, "the primary threat at Rockingham was chemical, not radioactive. However, preoccupation with radioactivity prevented the timely response to the explosion and chemical dangers."[4] The NTSB also concluded that

- "The initial notification of emergency response agencies was time consuming and of questionable effectiveness because of the inadequacy of the Seaboard Coast Line Railroad's contingency plan."
- "The emergency response plans concerning radioactive hazardous materials were inadequate."
- "An effective hazardous materials emergency response plan must include designation of the on-scene commander, delineate the coordination of effort between all organizations, require prompt establishment of a command post, and provide guidance for communications and control of access to the accident site."
- "The current system of classifying hazardous materials does not provide emergency response personnel with suitable information with which to diagnose the relative dangers and formulate operational plans."

The role of emergency preparedness plans is discussed further in a later section of this article.

The question of the scale of a potential accident for which preparation should be adequate also deserves consideration. The NRC and the Federal Emergency Management Agency (FEMA) have issued guidelines for emergency plans for site-specific facilities.[5] They have addressed a range of contingencies for these sites, including core melt-downs. For transportation accidents, the potential magnitude is extremely variable, but, even at the extreme, less catastrophic than the worst reactor accident. In a companion paper in this volume, Norton has summarized some of the accident-scenario literature.[6] He

3. U.S. General Services Administration and Federal Preparedness Agency, *Federal Response Plan For Peacetime Nuclear Emergencies (Interim Guidance), Annex I, Guidelines for Federal-State Relationships*, 26 (Washington, D.C., April 1977) [hereinafter FEDERAL RESPONSE PLAN].

4. National Transportation Safety Board, Special Investigation Report: On-Scene Coordination Among Agencies at Hazardous Material Accidents, 17, TO 1.112/2:NTSB-HZM-79-3 (September 1979).

5. U.S. Nuclear Regulatory Commission and Federal Emergency Management Agency, CRITERIA FOR PREPARATION AND EVALUATION OF RADIOLOGICAL EMERGENCY RESPONSE PLANS AND PREPAREDNESS IN SUPPORT OF NUCLEAR POWER PLANTS, NURREG-0654, FEMA-REP-1 (January 1980).

6. Norton, *Policy Issues in the Routing of Radioactive Materials Shipments*, 21 NAT. RES. J. (1981).

concludes that, apart from the possibility of sabotage of a shipment of high-level waste or spent fuel in an urban area, the worst-case outcome would involve tens of fatalities, not hundreds, and possibly the evacuation of hundreds or thousands of people. For organizing emergency preparedness, the potential magnitude of the accident is most relevant to planning for possible evacuations. Radiological injuries do not present the same degree of urgency as many other kinds of injuries. Thus, speed of response is most important for non-radiological injuries and for the decision to evacuate an accident site.

The issues concerning the designation of responsible parties for emergency response in general and evacuation in particular are interrelated. While offices of emergency preparedness exist at the state level, the first local official on the scene of the accident will make the important decisions, other than those pertaining to decontamination and other post-accident clean-up operations. The first responsible person at the scene normally is a fireman or policeman (or sheriff), usually the latter. In the unlikely event of a threat to the population in the zone of the accident—for example a possibly radioactive smoke plume drifting toward dwellings—this person might have to make an immediate evacuation decision in the interests of public safety. In New Mexico, for example, an evacuation decision is presently the responsibility of county-level officials of the state's Office of Civil Emergency Preparedness.[7] Clearly, this division of labor could cause inefficiency in the event of an accident requiring immediate decisions.

For purposes of limiting the potential for large numbers of injuries or fatalities in a radiological accident, the evacuation decision could be the most important part of emergency response. Therefore, organizational changes which would facilitate the flows of information required for that decision and timely implementation of it would constitute a clear contribution to improved emergency preparedness. A formal transfer of responsibility for accident-related evacuation decisions to the police would exemplify such a change.

The speed of emergency response can be determined by the adequacy of plans, efficiency of information networks, and a number of organizational factors. For accidents in transportation, the spatial distribution of response facilities also affects the speed of response. Thus, a fiscal question arises: should expenditures be made to locate the facilities at closer intervals along transportation routes? To answer this question, it is necessary to consider the reasons why speed

7. R. Cummings, H. Burness, R. Norton, THE PROPOSED WASTE ISOLATION PILOT PROJECT (WIPP) AND IMPACTS IN THE STATE OF NEW MEXICO: A SOCIOECONOMIC ANALYSIS, ch. 7, EMD-2-67-1139(s), TD 898 c.8 (Albuquerque, April 1981) [hereinafter CUMMINGS, WIPP].

of response is required. In all accidents, saving the lives of the injured clearly depends in part on quick treatment. Society has developed emergency procedures designed to provide timely treatment. Whether these procedures are adequate in the sense of timeliness may be a legitimate question, but for non-radiological injuries that question is beyond our purview. We have discussed the importance of time in regard to a possible evacuation decision, but for this issue timeliness would not be served by constructing facilities at closer intervals. Perhaps a marginal contribution to speed of response could be achieved by expanding the police force, so that on the average a patrolman in the field is likely to be within closer range of an accident, but the expected time savings from such measures would not be likely to be significant.

Finally, we consider the response requirements imposed by the nature of radiological injuries. For these injuries, special procedures are required, but time is not a particularly important factor. Existing medical handbooks state that providing first aid for non-radiological, life-threatening injuries is the first responsibility in treating victims of radiological accidents.[8] Radiological decontamination and treatment should be attended to only after this first responsibility has been satisfied. This brief review suggests, therefore, that the nature of radiological accidents does not justify additional expenditures for enhancing the speed of response. Expenditures may be required for other aspects of response capabilities, but not particularly for increased timeliness.

The training and equipment required for handling radiological accidents does differ from that associated with other kinds of accidents. The primary equipment requirement for hospitals treating patients exposed to radioactive contaminants is a diagnostic radioisotope facility. Many counties in the country presently lack a hospital with such facilities. Therefore, cases involving radioactive contamination would have to be handled elsewhere. A recent study[9] revealed that 18 of New Mexico's 32 counties do not have diagnostic radioisotope facilities. Seven of these counties do not have a hospital at all, and eleven counties with hospitals do not have these facilities. Given that radiological injuries do not present the same urgency as other kinds of injuries often do, the lack of radioisotope facilities in some locales does not mean injuries from radiation exposure will go untreated. The lack of such facilities, however, presents another kind of danger: an inadequately equipped hospital may refuse to handle a possibly

8. E. Saenger, MEDICAL ASPECTS OF RADIATION ACCIDENTS, U.S. ATOMIC ENERGY COMMISSION (1963).
9. CUMMINGS, WIPP, *supra* note 7, ch. 7.

contaminated patient, and the time required to transport him to another hospital may be critical for the treatment of other injuries.

In the ten years 1971-1980 (through May 8, 1980), there were 195 handling and transportation accidents involving radioactive shipments. Five of those events involved package failures which resulted in releases of radioactivity.[10] A total of 38 packages failed to the point of releasing radioactivity, out of many millions of packages shipped in this period.[11] This is a very good safety record, but clearly the number of accidents will increase as shipment volumes increase, and hence the argument for equipping virtually every hospital in the nation with a diagnostic radioisotopic facility therefore will carry ever greater weight.

Another equipment need concerns the first-on-scene officials. In light of the above discussion about possible evacuation of the affected area, policemen and firemen clearly require some means to evaluate the potential radiation threat to surrounding populations.[12] Prenotification has been mentioned in this context, and also installation of metering equipment in official cars is one logical step toward meeting this need, along with requisite training of local officials. One school of thought argues that evaluation of the radiation threat should be left to regional federal emergency response teams. This argument, however, fails to account for the risk that weather or other contingencies may prevent early arrival of the federal team. The California Resources Agency has come down firmly on the side of properly equipping local government response teams:

> State and local police and emergency crews are generally recognized as initially responsible for emergency action. Although some state and local police, fire, and emergency crews are trained and equipped with radiation detection instruments, most crews generally do not possess special knowledge or competence concerning radioactive materials. For this reason, state and local agencies must provide plans for the initial emergency action. This includes providing essential training and equipment to ensure that a properly trained and

10. J. McClure, E. Emerson, A REVIEW OF U.S. ACCIDENT/INCIDENT EXPERIENCE INVOLVING THE TRANSPORTATION OF RADIOACTIVE MATERIAL (RAM), 1971-1980, 2-3 Sandia Nat. Lab Rep., SAND 80-0899C, TTC-0100 (Albq. 1980).

11. It is likely that more releases occurred but went unnoticed: "perhaps one in ten improperly closed packages is detected and reported." ENVIRONMENTAL SURVEY OF TRANSPORTATION OF RADIOACTIVE MATERIALS TO AND FROM NUCLEAR POWER PLANTS, U.S. ATOMIC ENERGY COMMISSION, Appendix A, at 72 (December 1972).

12. *Guide and Example Plan for Development of State Emergency Response Plans and Systems for Transportation-Related Radiation Incidents,* REGIONAL TRAINING COMMITTEE, REGION VII, AND THE WESTERN INTERSTATE NUCLEAR BOARD (April 1975).

> equipped emergency response crew is immediately available. Since some injured persons may need special treatment, facilities capable of treating contaminated patients should also be available.[13]

Training is equally important in emergency response. Firemen may refuse to respond to a fire call involving suspected radiation contamination owing to their lack of training for such contingencies.[14] Both attitudinal training and training in the mechanics of radiation should be emphasized in preparing local officials for radiological accidents. For New Mexico, it has been estimated that the total discounted costs over 30 years of training and equipment for police, hospital staffs, and firemen, including retraining, would be slightly over $6 million[15] with a 6 7/8% discount rate. This outlay would bring the state's emergency response capabilities to levels commensurate with the risks imposed by the operation of the Waste Isolation Pilot Plant (WIPP). While there are not many nuclear waste disposal sites in the nation, most states are experiencing increasing volumes of radioactive shipments. A corresponding effort to upgrade emergency response facilities across the nation could lead to significant fiscal outlays.

The federal government has been defraying some of these costs by providing training to local officials through the Federal Emergency Management Agency (FEMA). To the extent that residents of particular localities may feel that they are bearing an undue share of the external costs associated with nuclear facilities, the pressure for federal cost-sharing in this area can be expected to increase.

b). Issues Related to Intergovernmental Relationships

The federal government's role in the area of radiological emergency preparedness is extensive. Generally, it involves three kinds of functions: issuing guidelines for state and local agencies to use in their own drafting of emergency response plans, maintaining a capability to respond to incidents involving weapons and other federally-controlled nuclear materials, and being prepared to assist states as called upon in radiological emergencies.

For several western states, the latter function is vested in the Joint Nuclear Accident Coordinating Center (JNACC) operated by the U.S. Department of Energy at Kirtland Air Base in Albuquerque. JNACC is prepared to send its specially trained personnel to the site of a radiological emergency and has done so on several occasions. This

13. REPORT OF THE SECRETARY FOR RESOURCES AGENCY OF STATE OF CALIFORNIA, TASK FORCE ON NUCLEAR ENERGY AND RADIOACTIVE MATERIALS, RADIOACTIVE MATERIALS IN CALIFORNIA 430 (April 1979).

14. Letter from A. D. Lujan, B. Martinez, to the New Mexico Environmental Improvement Board from the Albuquerque Fire Department in November, 1979.

15. CUMMINGS, WIPP, *supra* note 7, ch. 7, at 61.

agency clearly performs a valuable service, but it is complementary to, rather than competitive with, local emergency response personnel who may be on the scene long before JNACC personnel arrive.

State and local authority is unquestionably paramount in the area of emergency preparedness for radiological accidents. "It is certainly appropriate and within the constitutional and legislative authorities of the state governments to develop emergency response programs. . . ."[16] Federal agencies have acknowledged this fact. The GAO reports that "state and local authorities are responsible for implementing emergency measures because they 1) are usually the first on the scene at a transportation accident and 2) have the authority to take required protective measures, such as evacuation."[17]

The Federal Preparedness Agency (FPA, now a part of the Federal Emergency Management Agency, or FEMA) has made the same point:

> ". . . it is recognized that, under our constitutional form of government, those emergencies, unless they occur in Federally-controlled areas or involve Federally-owned material or equipment, are in first instance a matter of concern to State and local authority" [General Service Administration and Federal Preparedness Agency, April, 1977].[18]

Emergency response planning for transportation accidents is inherently more complex than planning for site-specific accidents. Responses may be called for at widely dispersed locations. Consequently, many different officials must be prepared to be the first responsible person on the scene. Accident conditions vary enormously, and post-accident radiation monitoring is less immediate than in the case of fixed-site facilities. It is impossible to drill citizens on emergency response measures, unlike the case of fixed-site facilities, given the large populations residing along the hundreds of miles of routes.

An adequate emergency response clearly may involve many of the usual emergency personnel, such as police, medical personnel, and fire fighters. An adequate response also involves individuals with specialized training in radiation detection and decontamination, radiological injury treatment, and other related areas. Above all, adequate emergency response requires effective communications among the different elements of the response team. Communication is probably

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16. Tucker, *The Transportation of Radioactive Materials: Federal Preemption v. State Regulation,* 47 STATE GOVERNMENT 122,126 (1974).

17. FEDERAL ACTIONS ARE NEEDED TO IMPROVE SAFETY AND SECURITY OF NUCLEAR MATERIALS TRANSPORTATION, U.S. GENERAL ACCOUNTING OFFICE, REPORT TO U.S. CONGRESS BY THE COMPTROLLER GENERAL, 25, GA 1.13:EMD-79-18, Wash., D.C. (May 7, 1979) [hereinafter FEDERAL ACTIONS].

18. FEDERAL RESPONSE PLAN, *supra* note 3.

the weakest link in many states' radiological emergency response capabilities.

Not all states have emergency response plans for radiological transportation accidents, but many are in the process of developing them. In South Carolina, state highway patrol officers receive training on a semi-annual basis for handling accidents involving nuclear materials. California also provides radiological emergency training programs for its highway patrol. In Colorado, emergency alert exercises are conducted periodically for the state's one nuclear power facility. New Mexico has a Radiological Emergency Response Plan which was most recently updated in August, 1980. There has been no attempt, however, to augment New Mexico's emergency preparedness for the WIPP.

At a general level, we can cite experience to date regarding the costs of emergency preparedness planning, and we can draw attention to the following points:

- Plans are needed; witness the case of the Rockingham, North Carolina, accident.
- Testing of the plans at intervals is crucial to their successful functioning in real emergencies: "to obtain a comprehensive picture of emergency planning at the State level, we sent a questionnaire to each State . . . thirty-six said they had plans for dealing with transportation accidents involving nuclear materials, but only eight had fully tested their plans through full-scale drills involving emergency personnel . . . the plans should periodically test emergency resources to reinforce training and to maintain the skills needed to respond to a serious accident."[19]
- There is a strong case for development of regional or county radiological emergency plans for those areas with potential nuclear waste transportation routes. The geographical size of the larger western states and the large number of local officials who would become involved in responses to accidents especially compel the development of such plans in the west. The Defense Civil Preparedness Agency[20] has discussed the substance of such plans, even for areas with populations of less than 5,000.

Tables 1 and 2 display estimates of historical levels of expenditure on emergency preparedness planning at the state and local levels. These figures are based on planning for fixed facilities, where smaller numbers of emergency response personnel are involved. Therefore, the corresponding figures for state-wide plans covering transportation routes would no doubt be higher.

19. FEDERAL ACTIONS, *supra* note 17, at 25, 29.

20. DEFENSE CIVIL PREPAREDNESS AGENCY, STANDARDS FOR LOCAL CIVIL PREPAREDNESS, U.S. DEPT. OF DEFENSE, D.14.8: L78 [1973] (December 1972).

TABLE 1

SUMMARY OF HISTORICAL STATE EMERGENCY PREPAREDNESS COSTS FOR NUCLEAR POWER FACILITIES
(in 1978 dollars; per power plant site)

State	Initial Planning Costs	Identifiable Recurring Costs*
Alabama	17,776	16,749
Arkansas	240,127	96,430
California	104,354	59,445
Colorado	99,697	20,333
Connecticut	23,696	32,361
Delaware	40,250	31,625
Florida	56,700	
Illinois	107,910	13,526
New Jersey	103,375	26,371
New York	56,236	98,959
Oregon	54,794	96,020
Tennessee	54,000	300
Washington	39,458	10,432
Wisconsin	15,796	
Total	1,005,199	502,551
Average	89,600	80,374

*Identifiable recurring costs come from the summation of updating planning costs, exercise costs, updating training costs, and updating resources costs.

Source: R. G. CUMMINGS, H. S. BURNESS, R. D. NORTON, op. cit. ch. 7.

c). *Methodological Issues*

Turning from institutional issues to methodological concerns, the extent to which benefit-cost analysis may be used in designing programs of emergency preparedness naturally presents an important area of inquiry. The costs of alternative programs are fairly easily established. The question turns therefore on our ability to measure the benefits of such programs. The benefits derived from improving emergency preparedness plans takes the form of avoidance of damages. The fact that we are dealing with infrequent, probabilistic events places us in the realm of expected values, and estimates of damages avoided must account for the probabilities of various events occurring. In principle, the estimation process requires the following kinds of information:

- comprehensive classification of possible accidents into different types, and estimation of the probability of each type occurring.
- estimation of the consequences of each type of accident.

TABLE 2

SUMMARY OF LOCAL GOVERNMENT EMERGENCY PREPAREDNESS COSTS FOR NUCLEAR POWER FACILITIES, ONE-STATE PLANNING
(in 1978 dollars)

County	State	Initial Planning Costs	Identifiable Recurring Costs*
Morgan Lawrence Limestone	Alabama	455,046	7,606
Humboldt	California	37,791	75,243
Sacramento	California	10,289	8,338
San Diego	California	41,176	38,122
Tri-Town	Connecticut	71,288	10,000
Citrus Levy	Florida	9,345	8,060
St. Lucie	Florida	3,750	3,750
Dade	Florida	5,154	
Oswego	New York	487	15,450
Westchester Rockland Putnam	New York	50,324	21,234
Total		674,650	187,803
Average		137,804	32,953

*Identifiable recurring costs come from the summation of updating planning costs, exercise costs, updating training costs, and updating resources costs.

Source: R. G. CUMMINGS, H.S. BURNESS, R. D. NORTON, op. cit. ch. 7.

- valuation of injury and loss of life, to the extent that it may be a consequence of some of the accident types.
- estimation of the amount of damages in each accident type which would be avoided with a specified improvement in emergency response capability.

Considerable effort has been devoted to attempts at quantification of accident probabilities and their consequences.[21] As the companion article in this issue by Norton shows, however, significant disagreement and uncertainty regarding these quantifications remains. Norton concludes that at present we do not have sufficiently reliable and comprehensive evidence estimates to permit acceptable derivations of "expected costs" associated with radiological accidents.[22] Some spe-

21. FINAL ENVIRONMENTAL STATEMENT, *supra* note 1.
22. NORTON, *supra* note 6.

cialists have argued that there are methodological reasons why reliable estimates may be unattainable.[23] For low-probability, high-consequence occurrences, such as release of radioactivity from a spent-fuel cask, we do not have a sample of historical frequency data (fortunately!), and hence estimates of accident probabilities must be derived from "fault-tree" engineering analyses. Apostolakis and others[24] have pointed out that fault-tree analyses require the scientist to anticipate *all* potential mishaps, few of which have ever been experienced before.[25] These and other authorities recommend that little veracity be attached to the absolute probability numbers developed through "fault-tree" studies, although such numbers may be useful for comparing the relative safety of different designs for a system.

Clearly this kind of fundamental knowledge problem poses important difficulties in attempting to compute the expected damages from nuclear transportation accidents, and hence the expected benefits from better emergency preparedness. Even if it were possible to overcome this particular problem, another one lies in our path: the difficulty of estimating the reduction in damages associated with a given level of emergency preparedness. Attempting this class of estimates would mean compounding the speculative nature of the numbers. Sinclair et al.[26] have argued that expenditures for preventive safety should be evaluated by comparing costs with expected benefits. The same framework would seem to apply by extension to emergency preparedness programs, but we would argue that empirical difficulties make Sinclair's approach infeasible in this field.

These brief comments should suffice to demonstrate that benefit-cost analysis—or its probabilistic extension—is not applicable to the area of emergency preparedness programs. What alternative methodologies remain?

Environmental economics in recent years has helped familiarize the *standards* approach, in which non-economic criteria are used to establish the desired magnitude of a program, and then economic analyses are used to help devise the most efficient means of achieving that magnitude. Examples include air quality standards and the toler-

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23. Apostalakis, *Probability and Risk Assessment: The Subjectivistic Viewpoint and Some Suggestions*, 19 Nuclear Safety 305 (1978).

24. MASS. DEPT. OF PUBLIC HEALTH, MASS. COMM. ON NUCLEAR SAFETY, *REPORT* (Sept. 1975).

25. For a further review of fault-tree procedures, *see* CUMMINGS, WIPP, *supra* note 7.

26. C. SINCLAIR, P. MARSTRAND, P. NEWICK, INNOVATION AND HUMAN RISK, THE EVALUATION OF HUMAN LIFE AND SAFETY IN RELATION TO TECHNICAL CHANGE (1972).

able level of pollution in lakes. Such standards are easier to establish when there are clearly defined thresholds or discrete alternatives. In the case of lakes, aquatic research has established thresholds for various pollutant concentrations beyond which certain species of fish cannot survive. The lack of an obvious threshold poses one of the most basic problems in developing and maintaining a consensus on what air quality standards should be.

For emergency preparedness programs, clear-cut choices exist. A fireman either has been trained to deal with combustion of radioactive materials or he hasn't; a policeman has radiation detection equipment in his car or he doesn't. Of course, there are degrees of adequacy in training, for example, but basically the choices are discrete in nature. The WIPP study reached the conclusion that an adequate level of protection for New Mexico could be guaranteed only by implementing certain training and equipment purchase programs, given that several dozen transportation accidents involving radioactive materials could be expected over the lifetime of the WIPP.[27] Other states might be well advised to adopt a standards approach to review the status of their preparedness for radiological transportation accidents.

CONCLUDING REMARKS

We would like to wrap up the foregoing discussion by listing the major points which have emerged:

- At the state and local level, emergency preparedness for nuclear transportation accidents needs more attention and resources.
- Pre-notification regarding the contents of shipments is necessary to enable state and local officials to carry out their responsibilities, but pre-notification in the form contemplated in most discussions of the issue may not be necessary.
- The potential decision regarding evacuation from the area surrounding an accident could be the most important post-accident decision from a public safety viewpoint, and yet the prevailing division of responsibilities in most states is not conducive to making this decision in a timely and informed manner.
- Emergency response facilities probably do not have to be spaced closer together along transportation routes for the sake of handling radiological accidents, but further investment in training and equipment for local officials is needed.
- From a public safety viewpoint, it is not wise to rely on federal regional response teams as substitutes for local capabilities.

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27. CUMMINGS, WIPP, *supra* note 7.

- The costs of training, equipment purchase, and development and testing of emergency response plans can run into millions of dollars per state.
- Economic benefit-cost analysis is not a useful guide to decisions on emergency preparedness expenditures, but the standards approach offers a promising framework.