TRANSPORTATION OF HAZARDOUS MATERIALS
Issues in Law, Social Science, and Engineering

Edited by

Leon N. Moses
Professor of Economics and Transportation
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To Rae, with love and admiration

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INTRODUCTION

Leon N. Moses

In June 1991, the Transportation Center at Northwestern University sponsored *Hazmat Transport '91: A National Conference on the Transportation of Hazardous Materials and Wastes.* The faculty associated with the center were aware that there had been many professional, industrial and government conferences and meetings on the subject. However, they believed that the unique capacity of the Transportation Center to bring together leaders from industry and government, as well as leading scholars from economics, law, engineering, psychology and sociology who have done research on the problems associated with the transportation of hazardous materials and wastes (hazmats), could produce a set of integrated insights and understandings that would go well beyond those of previous conferences.

The papers that make up this volume were all delivered at *Hazmat Transport '91*. From a legislative point of view, they tend to deal with issues associated with the Hazardous Materials Transportation Act of 1975 (HMTA), the original act passed to regulate the transportation of hazardous materials, and the Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA). There were talks and papers presented at the conference that focused on other recent legislation and transportation issues with which HMTUSA does not deal. The conference proceedings volume also had discussions and papers on significant managerial and regulatory issues that could not be included in this volume because of constraints on its size. Therefore, this essay is made up of three parts. The first explains some of the important aspects of HMTUSA and other recent bills that deal with the transportation of hazmats. The second part highlights some of the important ways in which industry has been attempting to deal with the risks associated with the transportation of hazmats as well as issues that executives and specialists believe are unresolved. The final part of the essay comments on the essays that appear in this volume. It highlights their major contributions, the important ways in which they relate to one another, and how, taken together, they present an integrated, multidisciplinary view of the problems that I believe comprise a unique contribution to the field.

ASPECTS OF RECENT HAZMAT LEGISLATION AND COMMENTS ON THE LEGISLATION

The Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA)

The HMTUSA amendments to the Hazardous Materials Transportation Act (HMTA) governing the transportation of hazmats contain provisions that govern federal preemption, highway routing, registration, response training, motor carrier safety permits, placarding and provision of information, and penalties for violations of laws and regulations.

State and local laws that cover the transport of hazmats are preempted if they are not substantively the same as federal laws and regulations. It is expected that states will establish routes for the transport of hazmats but those routes must accord with the federal standards issued by the U.S. Department of Transportation (DOT). There are states where there is likely to be great difficulty in arriving at route decisions. It is not clear what DOT will be able to do to cope with complex and lengthy legal hearing processes that involve conflicts between communities and between government agencies within such states. States will not be allowed to unreasonably burden interstate commerce, but that is a different matter. States are permitted to impose equitable fees with the standards of equity to be worked out.

HMTUSA requires training for employees involved in the loading, unloading, handling, and storing of hazmats, as well as those involved in emergency response. Documentation and certification that such employees have been trained and tested in the areas of their responsibility are required. The law is not precise as to who the hazmat employees are, but provides that anyone who directly affects safety is so designated. The fact that thousands of brokers, wholesalers, agents and other parties and their employees will be involved in shipping, handling, and storing hazmats will make this requirement difficult to enforce in meaningful ways.

Most shippers of the most hazardous materials will be required to register at least once every five years and pay an annual fee of between $250 and $5,000. The registration requirement applies to foreign as well as domestic companies. Firms involved in more than one hazmat activity need only register once. A broad registration requirement, one that goes beyond the most dangerous commodities, was viewed by several participants as an essential part of a safety program. In a recent rulemaking, DOT imposed a flat $300 license fee that a significant number of carriers will be required to pay. The proceeds from this fee will be used to fund the education and training of people who are the first responders to a hazmat spill.

HMTUSA also requires that DOT register and issue permits to carriers of the most dangerous materials. Given the short time frame DOT has to put the carrier permit system in place, the agency will probably have to rely on the Federal Highway Administration's (FHWA's) safety audit system and classification of carriers to which these audits give rise. This system rates carriers as satisfactory, unsatisfactory or conditional.

HMTUSA enhances and clarifies DOT's prior authority to impose civil penalties on persons who knowingly violate the law. It also defines what "knowingly" means by eliminating the inference that the term only encompasses reckless actions. "Knowingly" is interpreted to mean that: (1) a person has knowledge of the facts giving rise to the violation, or (2) a reasonable person acting in the circumstances and exercising due care would have such knowledge.

Docket HM-181 modifies the regulatory scheme governing the packages used for shipping hazmats from one based on specifications concerning packaging standards to performance-oriented standards. Under the new rules shippers can use any package performance criteria. The change gives them more flexibility than they have had, but increases shipper responsibility.

The approach that the U.S. adopted to packaging in Docket HM-181 is the same as has been adopted by the United Nations. This effort to achieve international uniformity in hazmat regulation as a way of facilitating international trade is an aspect of an important change that has taken place in hazmat transport regulation.

HMTUSA requires that carriers of all hazmat shipments provide an emergency 24-hour telephone number at which specific information for mitigation of the effects of hazmat spills can be obtained. HMTUSA imposes on shippers most of the burden for providing emergency response information. Carriers are only required to ensure that necessary information is available when the hazmat is offered for transportation. The information that is intended to assist those who first respond to an accident should cover such things as a description of the material, its primary characteristics, immediate hazards to health, risk of fire or explosion, and immediate methods of handling fires. This information can legally be provided in three different ways: (1) on the shipping document; (2) in another document that contains basic information, a Material Safety Data Sheet (MSDS); or (3) in an *Emergency Response Guidebook* (ERG) and a shipping document that is cross-referenced to it.

HMTUSA also deals with the transportation of nuclear wastes. The secretary of transportation is to undertake a study to determine the safety of using dedicated trains for highly radioactive waste and spent nuclear fuel. A study is also to be undertaken to determine which factors should be taken into account by shippers and carriers in selecting routes and combinations of modes that would enhance overall public safety. These studies have not been completed.

HMTUSA contains provisions for training emergency responders with funds provided by fees imposed on carriers. The section of the bill in which training is addressed has been described as the most complex and difficult section. A cooperative relationship, described as outstanding by several conference participants, has been worked out with a number of federal agencies.

The bill also takes up the issue of improvements in the Hazardous Materials Identification System. Many experts at the conference took the position that the amount of commodity flow information now available is inadequate, particularly for truck transportation. They also expressed concern that the current placarding system may not provide information on spills adequately or quickly enough. HMTUSA takes up the issue of improvements in the Hazardous Materials Identification System. The identification issues are to be thoroughly reviewed in a study now being carried out by the National Academy of Sciences. The study will consider the current placarding and labeling system and improvements that can be made in it. If experience with an improved system still reveals important shortcomings, an alternative computerized telecommunication system may be warranted.

More money will be devoted to inspection and enforcement under the new law. In the past, fines were too low and were often viewed simply as a cost of doing business. The new law increases civil and criminal penalties. However, it was pointed out that the awards assigned under tort law in the hazmat area have been much larger and that they act as a more effective deterrent to violations than those that are likely to be imposed under HMTUSA.

A pervasive issue that surfaced in conference papers and session discussions dealt with the schedule and budget for DOT implementation of studies and rulemakings. It was the general consensus that deadlines imposed by HMTUSA are optimistic at best, especially since many mandated activities have yet to receive funding approval.

U.S. Oil Pollution Act of 1990

Concern was expressed that the act fails to incorporate clear, realistic and uniform liability limits for discharges. Prior to the 1990 act the statutes of some seventeen coastal states provided for unlimited tanker owner liability for discharges. Most states which have passed legislation since the 1990 act have duplicated its liability provisions. Liability limits are provided under the 1990 act and subsequent state statutes, but they are breachable on findings of gross negligence, willful misconduct or violation of federal or state safety standards by owners, employees, agents, or contractors. How these standards will be defined by courts and applied by juries will determine the extent to which unlimited liability will continue to apply to discharges. The possibilities are seen as ranging from a realistic liability limit or, as a practical matter, no limit at all. There is no clear perception of whether the 1990 act or the pre- or post-1990 state laws will create a legal environment in which there is the potential for liability that goes beyond the financial resources of owners, charterers and their underwriters.

The lack of clarity on limitation of liability creates uncertainty for tanker owners, their underwriters, charterers, and cargo owners as to whether the cost of insurance coverage on voyages to the U.S. will continue to increase at a greater rate than the cost of similar coverage for voyages to other countries. Underwriters have been assessing a premium on voyages to the U.S. on the assumption that the new legislation will not lead to realistic and meaningful limitations on liability.

The Sanitary Food Transportation Act of 1990

Hearings that preceded the passage of this act showed that the practice of unsafe backhauling was not widespread. Indeed, there was no conclusive demonstration at these hearings that any human being had been harmed by such practice. While the act may prevent abuse in the future, it was asserted that at present it creates more problems than it solves. DOT will have a difficult time developing workable definitions for such terms as nonfood products, refuse, food and food additives, etc. Perhaps the best thing that can be said for the act is that without it and the cooperation it generated between the various committees of jurisdiction in the House and Senate, HMTUSA would not have been passed in the waning hours of the 101st Congress and signed into law by the president.

BUSINESS PRACTICES, AND INTERINDUSTRY, INTERAGENCY, AND INTERGOVERNMENTAL RELATIONSHIPS

A substantial amount of conference discussion was devoted to the problem of variability and lack of coordination within the Department of Transportation itself. Regarding penalties imposed for identical or very similar violations, some observers noted that there are great differences not only between modal administrations within DOT but also from region to region within modes.

Shippers and carriers are not the only parties who observe this variability in sanctions. A GAO study also criticized DOT for not setting administrative standards that would provide a more evenly balanced penalty system. In spite of the fact that each case is considered unique and therefore deserving of some degree of separate evaluation, industry is strongly in favor of development by DOT of a sanction guide that would give direction to the field and help smooth out some of the variability in penalties across and within modes.

In addition to variability in sanctions, there is variability between modes concerning which materials are listed as hazardous. At present, DOT's Research and Special Programs Administration (RSPA) does not include environmentally sensitive chemicals (ESCs) that do not pose a safety concern to human life. However, many ESCs appear on the Coast Guard list.

The American Trucking Associations (ATA) consider the federal preemption of technical regulations provided by HMTUSA as the most important aspect of the bill. The areas involved are: container and tank construction, vehicle placarding, package marking and labeling, shipping documentation requirements, and the definition and designation of hazardous materials. ATA has also urged uniformity in other areas, such as state registration and fuel fees. Uniformity in state regulations is viewed by ATA as a key to smooth movement of freight in interstate commerce.

ATA also looks forward to a rulemaking on routing. Once this rulemaking is completed, states and localities will not be able to pass laws on routing or pass time-of-day restrictions unless they conform to federal standards. Such conformity will eliminate state and local area route requirements that have the effect of exporting risk to other areas, and burdening the transportation industry with circuitous, costly routes. Uniform routing standards will make transport of hazmats safer and more efficient.

ATA also supports the registration provisions of HMTUSA. Enforcement of regulations will be easier if those who manufacture, transport, or deal in hazmats in other ways are known. Identification of carriers who are fit, willing, and able to transport hazmats will also make it easier for shippers to choose safe, reliable carriers.

ATA has recognized the need to change the placarding system used to identify carriers of hazardous materials. Placarding improvements will benefit emergency workers who respond to incidents involving hazmats. ATA has also sponsored a group, the National Incident Management Coalition, which promotes the idea of an organized plan to clear up highway incidents quickly and efficiently.

ATA considers that the tank truck portion of the motor carrier industry is beset by problems that are unique to it. The decade of the 1980s produced only two profitable years, 1981 and 1987, for the industry. The collective impact of deregulation, the so-called "Reagan Recession," the insurance crisis, and the merger/purchase activity of the decade eliminated one third of the tank truck carriers from the market.

Tank truck carriers are rather unique when compared to firms in the less than truckload (LTL) portion of the business. A typical LTL carrier has hundreds (if not thousands) of customers. Tank truck carriers may find their corporate existence is dependent on one or two major customers, generally the giant chemical companies. It was asserted that dependence of tank truck carriers on a few customers means that the customers dictate the quality of service that is provided and the price that is charged, and severely limit the profitability of operations. This issue is dealt with in the Braeutigam-Moses essay of the present volume.

In 1990 the chemicals industry announced an initiative, Responsible Care, to improve its performance in the areas of health, safety, and environmental quality. A total of 185 companies, which together account for more than 90% of industrial chemical production in North America, have committed themselves to the principles of Responsible Care. Participation in the program is a requirement for membership in the Chemical Manufacturers Association (CMA). All CMA members accept a set of 10 guiding principles of the Responsible Care initiative. These principles govern concern for health and safety in all aspects of the industry's operations, and also call for research to develop safe chemicals.

Responsible Care is unique in several ways. First, the public is directly involved in helping the industry shape initiatives, instead of being informed about them after they have been framed by the industry. Experts in the field of risk perception and communication make it clear that public participation in programs, not just by national and community leaders, but by ordinary citizens, is essential for effective communication. The public values direct contact with industry. Public understanding and support is increased if people have a way to influence decisions.

Second, the Responsible Care program is unique in that it requires each company to constantly improve performance, no matter the base from which it starts. An effort is made to achieve improvement in performance through implementation of a series of Codes of Management Practice. These codes deal with community awareness and emergency response, pollution prevention, process safety, employee health and safety, distribution and product stewardship. The codes do not express standards or dictate how a company should operate. Rather, they express performance objectives that encourage continual improvement.

Despite the best efforts of the petrochemical industry to prevent accidents and reduce the amount of damage, accidents do occur. The industry has funded voluntary programs and response organizations to help manage accidents when they occur. One such organization is CHEMTREC. It provides a coordination liaison for emergency response through an 800 number on health and safety aspects of handling spills and important characteristics of spilled materials. A second organization, CHEMNET, can provide a transporter of hazmats with a list of response organizations that have people who are professionally trained to handle emergencies.

The chemical industry has worked with the Association of American Railroads (AAR) through a task force that carried out studies in which some of the key causes of transportation accidents were identified. Initially it focused on some simple changes in equipment that achieved dramatic reductions in accident rates. The task force has also made recommendations on emergency response, improvements in tank car equipment, transportation practices, and systems safety analysis. In the area of emergency response it has identified the need for training fire departments and other small emergency response agencies. It has worked with communities along the routes through which hazmats are shipped. The task force has also worked to involve senior management of chemical and railroad companies in safety.

The railroad and chemical industries are considering collaboration on a new project involving the environmental problems posed by hazmat transportation. Ten of the most environmentally sensitive chemicals have been identified. The railroads have specified two things they would like shippers to do in this area. First, they want existing tank cars that handle these products to be retrofitted with more effective protective features. Second, they want shippers to work with them to draw up specifications for building stronger new cars in which these chemicals will be transported in the future.

In a separate initiative, the AAR and its member railroads have established a program that provides training in hazmat safety. It includes courses such as Tank Car Safety, Railway Emergency Response, and Occupational Safety and Health Administration (OSHA) operations. OSHA has developed rules which detail four levels of response to an incident. The AAR follows OSHA's guidelines in planning its courses. Given the growth in number of hazmat shipments, it has been estimated that a million or more people will have to be trained and kept up-to-date through new and refresher training courses. HMTUSA makes provision for raising funds for training but it remains to be seen whether the funds and facilities and procedures developed will be sufficient for the task .

Most accidents are attributed to human error and, in an immediate sense, the attribution is probably correct. However, the human factor argument can be stated in too simple a way. The human factor in accidents does not just mean the driver or the locomotive engineer. Accidents do not occur in a vacuum. They occur in a context that includes many aspects of corporate and governmental operations. The source of the failure may be in initial hiring practices and human resource management and training programs, in inspection and maintenance programs, and in the attitudes of upper management. The corporations involved in the production, storage, and transportation of hazmats can contribute to a reduction in accidents by creating an overall atmosphere of concern for safety within their companies, and having upper management involved in safety programs. A corporate safety department with a real budget and the responsibility for carrying out rigorous internal safety audits can make significant contributions to the safety of operations. In addition, as several participants suggested, there must be shared responsibility between shippers and carriers.

In the insurance area, companies have been forming risk pools, which are captive insurance organizations, in increasing numbers. Companies have been doing so in order to assure that they will have insurance in the future at predictable rates. The traditional insurance market has been highly volatile. In addition, many insureds are charged rates that exceed the loss potential to which they expose insurance companies. One conference participant asserted that the risk pool achieves economies of scale and is therefore able to provide coverage with smaller financial demands than an individually owned program. The success of a risk pool depends importantly on having participants who are homogeneous, not just from an operations standpoint but also in the environment in which they operate. The social-legal environment is particularly important in industries like the transportation of hazardous materials. Hazmat accidents that arise from similar circumstances can have significantly different claim costs due to legal standards and other factors that affect liability levels in the geographic areas where they occur.

In 1981, Congress enacted the Liability Risk Retention Act. It was then revised in 1986. The act permits pools to offer national coverage to member/owners by registering with the insurance department of a single state, so long as they inform the insurance departments of other states in which they provide coverage.

THE ESSAYS OF THIS VOLUME

Disclosure, Enforcement, Compliance and International Relations

The first of the essays in the volume is "Disclosure, Enforcement, and Compliance: A Shipper's Perspective on Compliance," by Don A. Boyd. It takes the position that recent legislation and rulemakings in the area of hazmat transportation make the shipping, handling, and carriage of hazardous materials more complex and detailed than before. Firms that are involved in these activities will face great difficulties and risks if they are not familiar with the new rules and laws and may lose the right to remain involved in hazmat transport.

The new law, HMTUSA, attempts to reduce or eliminate some of the inconsistencies that existed under the original act, HMTA. Many state and local laws that involve the transportation of hazmats are preempted if they are not essentially in conformity with federal laws and regulations. States can still designate routes for the transport of hazmats if they do not conflict with federal standards. If one or more states are involved in the designation of a through route, their routing requirements must not "unreasonably burden" interstate commerce. The author points out that shippers have been concerned about state and local fees for the transportation of hazmats. The new law specifies that the fees must be equitable but does **not** provide guidance for determining what is equitable.

HMTUSA requires that shippers of hazmats train their hazmat employees in the safe loading, unloading, etc. and emergency response to accidents that involve hazmats. The training requirements go beyond what had been required under the old law. The author believes that the legislation does not make clear precisely who is a hazmat employer or an employee. Still, he believes that most shippers, but especially large ones, will probably be able to institute new training programs that will comply with the new rules. However, there is likely to be more difficulty with the many distributors, jobbers, wholesalers and others who are involved in hazmats and are quite small.

The old law allowed DOT to impose civil penalties against persons who knowingly committed acts in violation of the law or the regulations issued under it. But "knowingly" was not defined. The new law is very specific about the meaning of "acting knowingly," defining it to be if: (1) a person has actual knowledge of the facts that give rise to a violation, or (2) a person acting in the circumstances and exercising due care would have such knowledge. It is very important to understand that under the new law DOT can seek civil penalties for actions or omissions that are negligently committed. The wording of the new law amounts to strict liability and should increase motivation to comply with the law and its regulations.

One of the dockets associated with the new law, HM-181, Performance-Oriented Packaging (POP), was supported by almost all shippers. Under the new rules, there is reduced reliance on engineering specifications of standards for packaging hazmats. Shippers now have freedom to use any package that meets performance criteria. The change reduces the volume of regulations and provides shippers with greater flexibility in hazardous materials packaging. However, it also increases shipper responsibility. It will be more difficult for a shipper to determine whether a package meets specifications. Under the new system, a hazmat release may trigger a DOT investigation. If DOT or an injured plaintiff tests the shipping package and obtains different results than the shipper/container manufacturer a violation may be alleged, even if it is only due to differences in testing techniques. Performance-oriented standards set only minimum packaging requirements. Thus, in the event of a package failure, a shipper could be held liable in an action that alleges a need to meet more than minimum standards.

The present position of DOT is that it is the shipper's responsibility to determine the suitability of a package. The shipper is responsible for making certain that the package is properly assembled and prepared for transport in full compliance with the standards set forward by the manufacturer of the package. Boyd makes the very important point that a consequence of POP will probably be an increase in litigation over injuries and damages that result from exposure to hazmats, with the courts playing a more prominent role in judging compliance than they did under the old rules.

The new requirements on emergency response, Docket HM-126C, call for additional response information on shipping papers and packages. They also require that emergency response information appear on transportation vehicles and be available at transportation facilities. The new rules will have some impact on all firms that are involved in shipment of hazmats. However, the primary responsibility will fall on shippers of hazardous materials. Among other things, they will have to maintain a 24-hour monitored telephone number at which there will be informed personnel who can provide the detailed response information needed to cope with an incident. At a minimum, seven types of information must be available to initial responders at the scene of an accident. These types include information regarding risks of fire or explosion and immediate precautions to be taken.

The overall message for shippers is that the new laws and regulations offer greater flexibility and a reduction in regulatory complexity. However, to avoid greater exposure to liability, those who are involved in hazmat shipping and transportation, but especially shippers, will have to maintain a thorough and careful paper record of all the steps they have taken in training, packaging, and initial response information if they are to avoid greater liability than they have had in the past.

The second essay, "Compliance and Enforcement Problems in Hazmat Transportation: Will the Hazardous Materials Transportation Uniform Safety Act of 1990 Make a Difference?" by William Kenworthy, accepts the goal of the recent legislation, namely to provide more safety in the transportation of hazmats than did the original legislation. Kenworthy questions whether the measures adopted by Congress are suitable or even likely to advance that goal. In part the difficulty is that there is so little knowledge about which carriers are transporting which hazmats, in what parts of the nation, and in what quantities. The only data available are estimates, and no one knows how reliable they are. Kenworthy asserts that the Interstate Commerce Commission (ICC), the agency that licenses interstate carriers of property, does not know how many common and contract carriers have operating authority that includes hazmats. The agency knows nothing about private carriers. Still less is known about the shippers of hazmats. At the present time, there is no way of identifying the shippers of hazmats, particularly the many small and seasonal shippers who are thought by many to be the major source of hazmat accidents and spills. The shipper identification problem is serious in rail transportation, but it is much more serious for motor transport. HMTUSA instructs DOT to cope with this problem by requiring registration of shippers and carriers of the most hazardous commodities and to consider through rulemaking whether others should be required to register. At present, registration is not required of most of the shippers, carriers, and third parties involved in hazmats. The registration process has a second goal: that of providing funds through licensing for the training of first responders. It seems clear that this goal would also be better served if the registration requirement were cast more widely.

HMTUSA provides for DOT to issue hazmat transportation permits for motor carriers. Entry into the field is to be limited to those who are found to be fit for the purpose. Carriers of hazmats must receive a safety permit from DOT to be exhibited in all vehicles that are used to transport four categories of the most dangerous materials.

Given the limited time that DOT has to inaugurate the permit system, Kenworthy believes that it will have to rely on the Federal Highway Administration's (FHWA) safety rating system under which carriers are classified as satisfactory, unsatisfactory, or conditional. The rating process does not entail physical examination of vehicles, drivers, etc. Rather, inspectors go over a list of 75 questions that deal with the paperwork aspects of safety, with judgements of adequacy based on subjective notions of what is standard in the industry rather than a firm set of objective performance standards. Moreover, since there are so many carriers to be inspected and so few inspectors, only about half of interstate motor carriers have been rated, and the ratings of many are five or six years old. Kenworthy questions whether FHWA's safety audit procedures, which were not designed to screen hazmat transporters for safety, is adequate to the task of identifying carriers who can transport hazmats safely. The problem is complicated by the fact that a significant number of firms leave and enter the industry every year.

Kenworthy asserts that Congress created a paradoxical situation when it established the rules for issuing permits for the transport of hazmats. A carrier who is authorized to transport hazmats may not be authorized to transport a material once it has become a waste because it has been used, spent, or spilled. Permits for the latter activity are issued by the Environmental Protection Agency (EPA). The difficulty is that the philosophy of EPA regulation and that of DOT are almost diametrically opposed. DOT struggles through preemption to achieve national uniformity as a way of achieving safety. EPA adopts a perspective that is heavily local in its approach to environmental regulation. It emphasizes regulatory decentralization and has gone so far as allowing some states to set up their own permitting programs for the transport of hazardous wastes.

HMTUSA tries to enhance compliance and safety by strengthening enforcement and defining new offenses. The first of the new offenses is misrepresentation of what is in a package. The second is tampering, which amounts to actions that make it difficult to determine what material is in a truck, by such things as defacing a placard or a container.

The final very important point made by Kenworthy is that the new law includes negligence as a basis for the imposition of civil penalties. Such penalties can be imposed if a reasonable person acting in the circumstances and exerting due care would have knowledge of the factors that cause an accident.

The book's third essay, "International Standards and Docket No. HM-181," by Lawrence Bierlein, makes the point that the United States no longer occupies the dominant position it held for many years in the setting of safety standards for the transportation of hazardous materials. In recent years, other countries, as well as regional groups, have developed their own expertise and different rules and approaches to regulation of hazardous materials transportation. The resulting differences, redundancies, and confusion have given rise to a movement to achieve greater international uniformity in the regulation of hazmat transportation. In a sense, this movement has an objective that is similar to that of federal preemption at the national level, i.e., reduce regulatory burdens on trade to facilitate its growth. Bierlein cautions that this move can have negative features that have not yet been adequately addressed in this country.

For some years, the international bodies involved in developing safety standards for the movement of hazmats questioned whether DOT's statutory authority to regulate safety in the interstate shipment and foreign trade in hazmats extended to the establishment of uniform international codes. HMTUSA clarified this matter by specifying that domestic U.S. regulations shall be consistent with the standards adopted by international bodies, though the secretary was to remain free to impose more stringent requirements if they were needed to protect the public. Nevertheless, in Bierlein's view difficulties remain.

Bierlein believes that DOT and the other agencies that become involved in setting international safety standards have not had enough funds to be as active as they must be if they are to be well informed, participate actively in many international meetings, and have an impact on the outcome of negotiations. The problem is complicated by the fact that there are numerous international bodies involved in the negotiations over safety standards and they often disagree with one another. An administrative structure exists within the United States that has some power to reduce jurisdictional difficulties. It is much more difficult to cope with such problems internationally because no one body is accepted as having the political power to reconcile differences.

Bierlein believes that regulatory confusion in the handling of hazmats increases the risk of accidents. He also expresses a concern that the desire to facilitate international trade may lead DOT to accept safety standards that are less protective of public welfare than have been provided by domestic standards. In this regard, but only as one example, he points to the acceptance of performance-oriented packaging. He indicates that many people believe the more flexible, European approach to packaging standards will result in lower quality packaging than has been in use in the United States to date. The quality issue and the possible increased liability exposure that could result from the adoption of POP were discussed in the Boyd essay, as noted earlier in this introduction.

Bierlein urges that it is essential for the U.S. government, industry, trade and other associations and groups to participate much more fully in international meetings and negotiations that deal with safety standards in the transport of hazmats than they have in the past.

Agency Conflicts, Nuclear Materials Transportation, and Federal Regulation

The fourth essay in the volume, by Melinda Kassen, claims that there has been great difficulty in achieving interagency coordination in regulating the transport of hazardous materials within the United States. Kassen makes the point that the lack of interagency coordination was a central feature in the hearings that led to the passage of HMTUSA. She adds that there were particular concerns about the transport of nuclear materials where regulatory authority is parceled out between three agencies: DOT, which has little expertise regarding nuclear materials; the Nuclear Regulatory Commission (NRC); and the Department of Energy (DOE). Part of the difficulty in achieving safety in the shipment of nuclear materials arose because DOE is a major shipper of nuclear materials and a federal agency that has been allowed to certify its own compliance with NRC regulations to DOT. Kassen believes that the kind of jurisdictional friction that arose in the transport of nuclear materials can occur in the transport of other hazardous materials. She adds that the lack of agency coordination with regard to all aspects of the international transport of hazmats is widely known to practitioners in the field.

The case that Kassen makes for how serious the interagency conflicts and regulatory gaps that existed in the transport of nuclear materials is very compelling. She indicates that DOT has the primary responsibility for regulating the shipment of nuclear materials. Under HMTA, DOT issued a series of regulations governing packaging, placarding, training of personnel, etc. However, because the agency lacked expertise in nuclear materials, it ceded much of its authority to NRC and DOE. It allocated to NRC the authority to regulate packaging and other aspects of the transportation of high-level radioactive materials from nuclear power plants. NRC also approves routes for the shipment of nuclear materials that require protection, but shippers must still submit routes that are compatible with DOT's routing regulations. NRC regulates the quality of the packages and containers used by commercial shippers of nuclear materials. However, DOT delegated to DOE authority to regulate packaging and other aspects of nuclear materials transport for which it was responsible under the Atomic Energy Act in its capacity as the sole producer of the nation's nuclear weapons.

This maze of regulations, overlapping authorities, and gaps in regulation led to a situation in which a very serious nuclear incident could have occurred. DOE, as a shipper of nuclear materials, employed a container that NRC had failed to certify for commercial shippers of such materials. DOE continued to use the container even after NRC raised serious questions as to whether it would prove worthy in an accident involving a crash and a fire. DOE terminated the NRC review of the container and continued to use it to make shipments for several years. Kassen asserts that the consequences of a serious accident involving a truck loaded with nuclear materials in the container in question would have been enormous.

The point made by Kassen is that the regulatory program for ensuring the safety of nuclear materials transportation is fragmented among federal agencies. The results are serious regulatory gaps, and inconsistent regulations between modes of transport and those who are doing the shipping. She also points out that there are weaknesses in the NRC certification process of casks used to transport nuclear materials. This includes the fact that NRC inspects very few casks during production by commercial firms, and that no one inspects DOE's cask manufacturers. In addition, it has become common to certify containers on the basis of computer-simulated accidents or small-scale-model testing rather than actual full-scale testing of prototype casks. Kassen believes that small-scale-model and computer testing can lead to incorrect predictions. Her position is that neither DOT nor NRC have credible cask inspection programs. The overlapping nature of the agencies' authorities leads to a situation where meaningful enforcement is not possible.

Similar agency difficulties exist in routing. DOT has established suggested routes for shipment of nuclear materials. However, it is waste carriers, as pointed out by Kenworthy above, who choose routes for the transport of nuclear wastes.

They are regulated by EPA, which has a very different approach to regulation than does DOT.

Kassen accepts that HMTUSA attempts to streamline the process of overseeing the transportation of hazmats. It grants major authority to DOT. The success of the effort will depend on interagency coordination and cooperation. Fundamentally, the success of HMTUSA will depend on how well the agencies can suppress their conflicting institutional goals and motivations. The relevant agencies—DOT, DOE, and NRC—have so far failed to develop a coordinated approach to the transport of nuclear materials. The success of the HMTUSA goal will depend on whether or not the personnel of these agencies who do the coordination want to make it work.

The fifth essay, "An Economic Review of Monitored Retrievable Storage for Spent Nuclear Fuel," by Geoffrey Rothwell, is related to the Kassen essay in two important ways. First, it concentrates on the problems associated with nuclear materials, especially spent nuclear fuel, which, because of its high radioactivity, Rothwell sees as posing unique transportation problems as a hazardous material. Second, failure to resolve the very important and pressing problem of where to store such fuel has little to do with engineering; in his view it essentially represents a failure of the political process.

Until late in the 1970s, the electric utilities that employ nuclear reactors assumed that nuclear waste would be recycled through chemical reprocessing. Federal reprocessing plans were rejected in 1977 because of fears of nuclear proliferation and cost considerations. This decision meant that something had to be done to provide storage capacity because the on-site storage capacity at utility sites was filling up. The situation required that such capacity be expanded or other repositories be developed. After years of debate, Congress passed the Nuclear Waste Policy Act of 1982 (NWPA). It called for the selection of long-term repository sites that would safely store the waste for at least 10,000 years.

Five years after the passage of the bill, and with basically nothing accomplished, Congress constrained the site-selection process. Only one site was to be recommended. NWPA had originally called for identification of three possible sites. In addition, DOE was constrained from selecting a site that lay below an aquifer. That left Yucca Mountain, Nevada, as the only site. Amendments to NWPA in 1987 called for a commission to study the feasibility of a shorter-term solution known as Monitored Retrievable Storage (MRS). Rothwell reviews the commission's report. He considers the commission's cost and transport assumptions. In part, his objective is to expose the kinds of difficulties that DOT is likely to encounter in producing two studies that HMTUSA imposed on the agency: (1) a study of the safety of trains dedicated to transporting spent nuclear fuel compared to other methods of rail transportation, and (2) a mode and route study to determine which factors shippers and carriers should take into account in selecting routes and modes which would enhance overall public safety in the transport of high-level radioactive waste and spent nuclear fuel.

The MRS Commission employed two formal models in its work. One dealt with overall risk and cost. The second was a transportation risk and cost model. Rothwell finds some fault with the technical aspects of the commission's work: the models did not allow for nonlinear tradeoffs between cost and exposure; the costs employed were expressed in constant 1989 dollars, which assumes that all prices rise at the same rate over the planning horizon, which he feels is incorrect because it understates future transportation expenses.

The real problem with the MRS report is that the commission found it politically infeasible to employ actual potential locations for MRS sites. Rather, the centroid of two of the six regions into which the United States was divided were selected. The risks associated with these two easternmost centroids were then averaged to form a composite location. The commission did not deal with actual routes and costs in reaching the composite centroid. Rather, it employed average transportation costs over the entire region and the routes leading to it from all origins. Rothwell also finds similar fault with the commission's fatality calculations, which again are based on averages. He states that fatality calculations depend crucially on individual exposure, not on exposures to groups of individuals. Therefore, specific populations must be considered. However, because of political constraints placed on the commission, it could not consider actual sites for MRS storage in estimating fatalities, just as it could not consider actual transport routes and the costs that are specific to them.

Under the assumptions that political factors imposed on the commission, its report found little difference between the cost and exposure levels of various alternatives: no MRS storage facility, an MRS site linked to a long-term storage site, and an unlinked site. Unless DOT is empowered to deal with actual sites, actual routes, and actual population exposures, its two transportation studies are likely to do little to identify ways in which the nation can solve a very important social problem. On-site storage capacity at utilities will be filled at half of the nation's reactors in just three years. It is essential that a concrete plan be developed very soon to cope with the problem of storing and transporting nuclear waste and spent fuel.

The sixth essay in the volume, "Analyzing Routes for the Transportation of Hazardous Materials Including Radioactive Waste and Spent Nuclear Fuel by Use of Effective Risk Estimation," by Phillip Olekszyk, deals with the role of the Federal Railroad Administration (FRA) in providing for safety in the transportation of hazmats in general and nuclear materials in particular. The basic theme of the paper is given in the opening sentence of the abstract, where the author takes the position that the FRA contributes to the safe routing of all movements by assuring that all routes are safe for all commodities.

This implies that FRA has very few directives on safety that deal with special problems that may exist in the transport of hazmats and nuclear materials and wastes by rail, either as a matter of through routing, connecting rail service, or intermodal service. Indeed, the author makes it clear that there are currently no published regulations pertaining to the rail routing of hazmats, including radioactive wastes and spent nuclear fuel. He indicates that there are quasi-regulations that govern the routing of materials that are poisonous by inhalation. In the case of spent nuclear fuel shipments, FRA does have a policy of inspecting the entire rail route on which such shipments take place twice a year, operating practices annually, and the equipment employed in a shipment prior to use. Nothing special is done with other hazmats.

The basic position of FRA is that it grades track into six categories based on quality and maintenance. Maximum allowable operating speeds are set for each class of track. The speeds vary from 110 MPH for a freight train on the highest quality track to 10 MPH for the lowest quality. Olekszyk and other experts (including Theodore S. Glickman in *Analysis of a National Policy for Routing Hazardous Materials on Railroads*, U.S. DOT Draft Report, 1980) have taken the position that diversion of shipments from high to low quality routes would increase the risk of accident.

The Department of Energy conducted two studies on the routes used to dispose of wastes associated with the Three Mile Island incident. One of the studies had no constraints imposed on it other than origin and destination. It developed a risk estimation model by incorporating accident statistics and wayside population densities along each route that entered into the study. The accident statistics employed in the model were derived from FRA's incident reporting system. The rail traffic data were derived from the ICC carload waybill sample, and population densities were based on county level figures.

The accident statistics employed in the study were not for hazmats, and were not specific to the actual physical routes that entered into the study. The same can be said for the rail traffic data on these routes. It is questionable whether county level population figures are a sound basis on which to judge population exposure to radioactivity along specific routes. Finally, it should be added that the decision to select highest quality routes does not take into account the degree of train congestion on them, and the further fact that these routes are the ones where passenger and freight trains share the track while moving at different allowable speeds.

FRA does have some safety regulations regarding the movement of substances that are poisonous by inhalation, though even here it does not deal with materials that become poisonous as a result of a fire. The agency does carry out inspections of trains and routes that are used for the transport of spent nuclear fuel. Apparently, it has decided that there is no need for safety regulation of all other, the great mass of, hazmats. It does inspect and grade track. However, it has no rules that prevent very dangerous materials from being transported on the lowest classes of track, nor does it direct that the most dangerous materials be transported at lower allowable speeds than regular frieght.

Technical Risk Assessment Models, Data Needs and Difficulties

The next five essays in the volume deal with technical aspects of the risk appraisal process that is employed in evaluating alternative transportation options. The techniques involved in the process, the data employed, and possible weakness in both the underlying logic and the data are examined.

The first of the papers in this series, the seventh essay in the volume, is entitled, "Working Together to Build a Safer Future," by Mark Abkowitz. The author identifies five areas that must be considered in efforts to improve safety in the transport of hazmats. They are: (1) routing, (2) evaluating and communicating risk,

(3) emergency preparedness, (4) data collection and management, and (5) inspection and enforcement.

Abkowitz believes that the routing issue is one of the most contentious that has to be faced in making decisions on the transportation of hazmats. Shippers and carriers want the most economical routes, usually those that are highest in quality and connect major population centers. Emphasis is on the lowest cost routes in motor carrier as well as rail transportation. This emphasis would have the effect of shifting hazardous materials traffic on to a few routes that would carry significantly greater quantities of dangerous goods than other routes. Such a shift would tend to benefit many communities at the expense of a few "losers." The other aspect of routing, namely risk reduction, would tend to divert shipments away from heavily-populated areas to more circuitous, higher-cost routes with low population densities.

Subject to some overall guidelines from DOT, states and, where long distance traffic is involved, groups of states have the responsibility to make routing decisions. These decisions must not place undue burdens on interstate commerce. This provision allows for considerable freedom in designating or eliminating certain routes from consideration. The criteria that states select and the weights they attach to them are the result of subjective evaluations which can lead to radically different routing decisions. Abkowitz believes such differences in results demonstrate that when risk criteria are applied, alternative routes could be selected that differ from those currently used by industry. On this point, he ends the routing discussion with the obvious but very important idea that states are going to have to decide "how safe is safe enough?" In the light of essays that are to follow, they are also going to have to decide what data they need to make such decisions.

The author views risk evaluation, and the underlying technique of risk assessment, as necessary for making rational decisions on how to move hazmats safely. Risk assessment is performed in order to understand the likelihood of a potential incident that involves a particular commodity movement, and its threat to public health and damage to the environment. Risk assessment has become an accepted tool in management decisions by industry and government. Abkowitz implies that the basic logic of the approach is now fully accepted and that it only remains to obtain the data necessary to implement it properly. Other authors in this volume, namely Slovie and Clarke/Freudenburg, raise serious questions about the risk assessments that are carried out by narrow technical specialists.

Whether the technique is so sound structurally that all concerned can now go on to concentrate on data issues is something about which I have some doubts. The risk models employed in hazmat transportation studies are strictly linear in the effects that they estimate will follow an incident. Thus, consider the effects of accidents on two communities that are absolutely identical in all regards but one, the probability of their suffering a given type of hazmat incident. The probability is 10 percent for one community and 20 percent for the other. Since risk models ignore economies and diseconomies of scale, they conclude that the second community will suffer twice as much in damages as the first. Such a conclusion has neither intuitive nor empirical appeal when indirect as well as direct effects are taken into account.

Questions can also be raised as to the kind of data that risk specialists want in order to implement their models. Later essays in this volume raise questions as to whether risk specialists consider issues that are of the greatest concern to communities, i.e., their external and nonlinear impacts on quality of life in communities.

Abkowitz believes that a great deal of progress has been made in developing plans for emergency preparedness. Elements of such progress include quick access to experts, having proper basic equipment in place, knowledge of what to look for and how to identify products that are spilled, and basic level of knowledge at dispatch, police, and firefighter levels. However, he is concerned by the great reliance that the system places on volunteers. Volunteerism has problems, particularly in hazmat emergency preparedness where advanced communication, information gathering, and highly skilled response capabilities are required.

Abkowitz is encouraged by the greater emphasis that has recently been placed on ensuring that existing safety regulations are followed, and by the increase in inspection resources that have been made available for oversight of vehicle and terminal operations. He believes that there should now be some shift of emphasis toward implementing cost effective programs, with the key issues being cooperation, communication, and training.

The essay by Mark Turnquist and George List, "Multiobjective Policy Analysis of Hazardous Materials Routing," contains a formal model which, taken in its own context, is logically satisfying. It is a linearly structured model that is designed to offer decision makers policy options in regulating hazmat truck transportation routes. The model does not attempt to minimize some objective such as fatalities and injuries, or transportation costs. Rather, it offers policy makers a way of seeing what the quantitative tradeoffs are between specified criteria on alternative nondominated routes. The crucial aspect of the model is the meaning of the term "nondominated" and how the identification of such routes rests on the number of criteria that the policy maker feels should be considered. Let us turn first to the meaning of the term.

For the sake of simplicity, assume that policy makers are only concerned with two criteria, cost of transport and population exposure to a spill, and that there are only three possible routes, A, B, and C. Route A is the lowest in cost of the three, say $5, and has a population exposure of 10,000 people. Route B imposes somewhat higher costs on carriers and therefore shippers, say $7. But it exposes only 2,000 people to the dangers of a possible spill. Route C involves a transport cost of $8 and has a population exposure figure of 11,000. Route C is dominated by A and B and is thereafter left out of the analysis. Policy makers must now make the choice they believe best suits those they represent as between transport cost and exposure by choosing either A or B.

The authors apply their model to an actual case in which hazardous wastes are transported in the Capital District of New York state—an area of 900 miles with a population of 900,000 people. The nodes and major roads in the area that were to enter into the analysis were specified from the outset. Others were left out. The quantities of waste originating at each origin and destined for a treatment plant were also specified.

The authors list six factors or criteria that federal legislation indicates should be taken into account in making routing decisions. Their analysis of the actual problem on which they were working employed only four of the six criteria mentioned in the legislation: operating cost, accident rate per trip, population exposure, and number of schools. They found nine nondominated routes, which they then arranged into three groups, A, B, and C. Group A contains only one route. Group B contains four routes whose ratings on three of the four criteria differ in nontrivial amounts. The same is true of the routes in group C. Policy makers could choose between the groups or stay with the actual figures for each of the criteria on each of the nine routes and make routing decisions. One of the important advantages to policy makers that rely on such an analysis is that they are much less likely to find themselves having difficulty with DOT.

The Turnquist-List approach to route modeling is clearly state of the art analysis. Still, the editor of this volume believes there are possible weaknesses that should be considered.

First, the chance that the analysis will end up with a relatively few nondominated routes between which policy makers can then choose depends very importantly on the number of criteria the model considers, and how many routes can be eliminated from consideration even before the formal analysis begins. Whether the various parties to a routing decision, principally the general public and industry, will accept the choices made by elected officials will depend on the criteria employed, and the basis for the decisions to eliminate certain routes at the outset. Were the choices based on engineering, economics, or industrial and political pressure?

Second, the present model and all the other routing models with which this writer is acquainted fall into the category of what economists call short run analysis. They do so in the sense that they fail to take into account the fact that since routing can have significant impacts on transportation cost, routing decisions can cause major shifts in the geographic patterns of the industries affected; major shifts in the pattern of origins and destinations of important industries can clearly be one of the effects of routing decisions. Such changes can require further changes in routing. It is a serious error to proceed as if choices that effect the costs of transporting goods will have no impact on where industry locates, where it ships its outputs, and from where it receives its inputs.

Third, even in the short run, routing decisions that have impacts on transportation costs can change the quantities of hazmats that are associated with given origins, destinations, and highway nodes. One cannot really do as Turnquist and List do, namely, begin by specifying the quantities that originate at various places and assume that routing decisions will not affect those quantities and how they are allocated geographically, even in the short run, from existing plants.

Fourth, the issue of linearity must be taken up again. Routing models begin by estimating the cost of moving freight on different routes. Those costs are then left unchanged even if traffic is diverted from a number of routes to a few that are designated for the transport of hazmats. In other words, routing models ignore congestion effects. Those who study motor carrier transportation know that congestion is an important factor in the costs associated with different routes. If routing decisions lead to increased congestion, costs can change as can the values associated with other criteria, such as the probability of a spill. Such changes offer serious challenge to the basic idea of dominated and nondominated routes. Routes that were left out initially because they were dominated on the basis of cost or other criteria can become more attractive. They would have to be brought back into the analysis as freight movements on designated routes increase. Growth in traffic and congestion effects can also change the relative evaluations of the nondominated routes.

The linearity issue is also troublesome in the economy and diseconomy of scale implications of accidents and spills. As indicated above, routing models assume, for example, that a doubling of traffic on a route leads to an exact doubling of accidents, incidents, social costs, private costs, etc. so that the average and incremental costs of accidents are unchanged. That is highly unlikely to be the case.

The paper by George List, "Siting Emergency Response Teams: Tradeoffs Among Response Time, Risk, Risk Equity, and Cost," employs a formal model to choose sites for emergency response teams so that certain objectives are minimized, such as average and maximum response time, and the average and maximum levels of risk imposed on the region's population. In other words, the model has multiple objectives. It employs the nondominated route approach used in the Turnquist-List paper. According to the author, the model can be used for horizon, which would seem to imply long-term, analysis. It can also be used in staged decision making. The area studied is the Capital District of New York state.

The model begins with 19 sites that have been identified as possible locations for hazmat response teams. List indicates that all of these sites are existing fire stations and that a few already have some response capability. The goal of the model is to determine how many response stations are required and where hazmat teams should be placed. Critical to the solution is the value of the response time from the various response sites. The response times are intended to reflect how long it would take a team to bring a "typical" incident under control. Response time is the sum of four time elements. *They are specified as fixed inputs into the model from the outset*, and are derived from a number of different sources. The four elements are: (1) time required to notify a response team, which depends on whether or not personnel are on duty and what kind of communications technology is available; (2) mobilization time, or how long it takes a response team to organize itself and get under way; (3) transit time, or how long it takes a team to arrive at the scene of an incident; and (4) containment time, or how long it takes to bring the incident under control and contain the contaminant. List states that the last has great variability and is highly dependent on the nature of the incident. He adds that no data exist on this component. Fifteen minutes was assumed in the study, but he notes that much longer times are clearly possible.

List found that in his case study only three to five teams were required to effectively reach the minimum values possible were all 19 potential sites to be employed. He indicates that to achieve this result, the locations of the teams have to be carefully chosen. The multiobjective methodology allows identification of the tradeoffs among objectives, using nondominated or efficient alternatives only. It is rather surprising to learn that a small number of teams can "effectively" reach the minimum values possible when all nineteen sites are employed. One would expect that transit time would be much greater when there are a small number of sites. Perhaps these sites are located on major throughways. However, even if they are, they must also have to travel the minor roads that must be used in reaching many areas.

List does not make clear whether the sites selected are also supposed to stand ready to respond to normal fire department incidents as well as hazmat spills. If that is the case, the issue of whether the two activities might interfere with one another should be considered. In other words, is it possible that there are diseconomies of scope?

The claim that the model can be used for long-term (horizon) planning as well as staged planning is also surprising if one envisions long-term changes in the size of the region, in the geographic distribution of the population, and in the amount of hazmats transported in and through the region. The validity of the claim would seem to rest on there being zero adjustment costs of relocating teams and substantial amounts of complex equipment from sites selected in the short run to sites required in the longer run.

The paper does not deal explicitly with costs, though the word does appear in the title. It would be interesting to know how costs and benefits would vary as the number, and therefore the locations, of response teams varies. The title of the paper also makes reference to risk equity; however, it does not explain how the multiobjective model approach can be used to investigate issues of equity and justice. An area that is distant from one of the selected hazmat sites will be served less well than one that is close to a response team. A model that reveals the impacts on different areas of having some rather than other sites chosen as hazmat response locations might help policy makers cope with issues of justice if they knew the impacts of the locational choices on different areas. However, to do that adequately, the model would have to show how containment time and, therefore, damage to people and property, vary with transit time. But the model is not structured that way. It fixes containment time from the outset and treats it, unrealistically in the editor's view, as being independent of how long it takes a response team to arrive at the scene of a spill. It would seem that the linearity assumptions of the model limit its policy usefulness.

We turn now to two papers that deal with the data needs and serious data difficulties and inconsistencies that characterize the risk assessment process. One of the papers, by Antoine Hobeika and Sigon Kim, is entitled, "Databases and Needs for Risk Assessment of Hazardous Materials Shipments by Truck." Hobeika and Kim evaluate the quality, adequacy, and structural problems associated with three of the databases that are central to risk assessment. They are the accident, incident (a spill is an incident and follows and accident), and exposure (how large is the population that is put at risk by a spill?) databases.

Risk assessment of hazmat movements is generally determined by multiplying the probability of an accident by its consequences. The probability of an accident that results in a release, an incident, is derived from truck exposure data. The exposure data record the volume of hazmat movements on the highway network. The consequence data provide information on the surrounding population, property, and environment that could be affected by a hazmat truck release.

In order to carry out a risk assessment, different databases have to be put together. It is necessary to force a fit between disparate sources of data, often collected for different purposes. Mismatches between accident, incident, and exposure data restrict the ability of specialists to carry out valid studies related to hazmat transportation safety. Consequence analyses should take into account the number of people exposed, the value of property, and the impact on environmentally sensitive areas exposed to a release. Very few studies have taken up the environmental consequences because such analyses would require site-specific data.

Hobeika and Kim make a very serious criticism of current risk assessment work. They say that the three components—incidents, exposure, and consequences—are equally important in conducting a meaningful risk analysis, but that the databases that pertain to the first two elements are inadequate. They support their position by showing that there are important differences in the relevant data between states, and between states and national sources. They also make the point that the accident data employed in risk assessment come from overall truck accident data rather than for hazmats. In a paper that appears later in the volume, Moses and Savage show that there are important differences in accidents among firms that carry different hazmats and general freight.

The lack of site-specific information on accidents and releases requires that certain values be used that are referred to as national default values. The difficulty is that these values are not likely to adequately represent what happens on specific highways in different areas of the country. The authors go on to make the very telling point that the use of national default values means that the minimum risk route is the one that avoids high population density areas, major employment centers, and critical environmental areas. Essentially, Hobeika and Kim take the position that there is little to be gained in performing a full risk assessment study if national default values play a major role in the study.

Hobeika and Kim conclude that existing databases do not provide sufficient information for risk assessment of hazmat truck movements. As a result, routing analyses and mitigation measures are not based on sound inputs of risk values. States have accident record systems that differ from one another, which makes nationwide analyses very difficult. They recommend that states adopt the National Governor's Association procedure for uniform truck accident reporting. Such data require that there also be geographic commodity flow information by hazardous materials commodity groups.

In their paper, "Uncertainty in the Estimation of Risks for the Transport of Hazardous Materials," Saccomanno, Stewart, and Shortreed accept that significant advances have taken place in the analysis of the risks involved in the transportation of hazmats. They state that in part the advances are the result of a better understanding of the risk analysis process, but add that there have also been some improvements in databases. Nevertheless, the basic position of the authors is that hazmat transportation risks are unverifiable, rare events with possible high consequent damages. As a result, the analysis of these risks remains plagued by difficulties of validation and uncertainty in its predictions, to the point where results are not viewed as credible by the informed public. The paper explores some of the sources of uncertainty in the various components of risk analysis in the transport of hazmats.

The authors indicate that there is uncertainty about each of the six components involved in the risk analysis process. They include such things as how far different materials will disperse after being released in an accident, the probability that a release will take place in the event of an accident, estimation of the risk to population and environment from an incident that involves specific materials at specific kinds of sites, etc. The sources of uncertainty in each of the components depends on the kinds of controls that are placed on vehicles that transport hazmats. Since information on such controls is often lacking, average values, reminiscent of the national default values discussed in the Hobeika/Kim paper, are employed. Another source of uncertainty is the omission of significant factors from components of the risk model. Grade crossing accidents and intersection accidents for rail and truck are mentioned as examples. They are an important source of accidents that are omitted. The authors also believe that there may be bias in the results obtained in a risk analysis because the inputs into the process are estimated conservatively. Their position is that biases in individual risk components can produce cumulative biases in final results.

Uncertainty may also arise from geographic differences that affect risk and assumptions concerning the application of the process. Lack of data in one area can cause data from other areas to be employed for the purpose of calibrating a risk assessment model and its components. However, differences in the nature of operations and in the mix of traffic in different areas can give rise to differences in derailments and corresponding release probabilities.

The authors draw on a variety of studies to show that there are significant differences in rail and truck accident rates by nation, by region of a nation, and in release probabilities in the event of an accident. Since there are relatively few releases some studies use all releases from all dangerous goods, regardless of type of material involved. Since containment systems for most dangerous materials are designed with the particular material in mind, use of aggregate data may produce significant errors. In addition, data on the size of releases and the size of impact zones associated with different materials are not adequate.

Finally, the position of the authors is that even if accident rates, release probabilities, and release sizes can be treated as generic in nature, the final component of the risk analysis, exposure, requires site-specific inputs that are difficult to obtain. They include such things as air temperature, weather conditions, air turbulence, and wind speed, as well as data on day and night time populations and the geographic distribution of population with respect to predominant winds. The authors believe that much of the inconsistency surrounding the risk analysis process results from differences in these types of location-specific features.

Social Views and Perceptions of Risk

The next two papers in the volume approach the issue of risk from psychological and sociological points of view. The first of these papers, "Perceptions of Risk:

Paradox and Challenge," by Paul Slovic, deals with how the public perceives risk rather than the way that specialists measure it. The paradox referred to in the title is that people in many industrialized countries have on average become healthier and safer but have become more rather than less concerned about risk. They have come to feel more vulnerable and oppose the introduction of new, more complex technologies, which brings the public into conflict with government and industry.

Two explanations are offered for the growing fear and concern on the part of the public. The first is simply that people with higher incomes place a higher value on their lives. As a result, they are more cautious about risk and more concerned about threats to their lives. The second explanation is that a change may have taken place in the nature of the risks to which people in highly industrialized societies are exposed. There may be greater potential for catastrophe because of the complexity, potency, and interconnectedness of technological systems and substances. Millions of people over broad areas have in fact been exposed to the effects of local breakdowns in modern technological systems.

Slovic offers an explanation of people's responses to risk. The explanation involves two factors. Factor 1 is labeled dread risk and involves perceptions of lack of control, fatal consequences, and the potential for catastrophe. Factor 2 involves hazards that are perceived as unknown, unobservable, and having long-term effects. The greater the ranking of technologies in these two factors, the more people want regulations imposed that will reduce current risks from them.

Risk specialists measure the effects of an accident in direct terms. They attempt to measure the direct effects and costs on people and property in the area where the accident occurred. The author notes that in reality the impacts of an accident can go much further geographically and have indirect effects and costs in areas far removed from the scene of an accident. The indirect costs can far exceed the direct costs. The Three Mile Island incident caused little actual damage in the area where it occurred. However, it imposed immense costs on the entire nuclear power industry. It led to reduced reliance on nuclear power and an increase in imports of oil. Slovic refers to this spreading out of the effects of an incident as social amplification and offers several explanations for why the phenomenon has become so prevalent. One of them is that communication technology conveys vivid knowledge of all details of an accident almost immediately and to the entire nation.

Slovic also offers advice on how communication of knowledge about risk can be improved between the public on the one hand and industry and risk specialists on the other. He says that risk communication cannot be a one-way street, from the experts to the public. It needs to be a two-way process based on trust and mutual respect. Each side, he asserts, has something to learn from the other. The experts have sophisticated techniques but they tend to focus on the easier problems and elements of risk, those that can be quantified. Lay people have a broader qualitative view of risk that involves such things as whole community effects, impacts on quality of life, impacts on future generations, etc. The fact that these concerns and effects are not quantifiable does not make them less important than those with which risk specialists deal. Moreover, the concerns raised in the two preceding papers about quality of data raise questions about how reliable the quantitative risk studies are even in their treatment of direct impacts and costs of accidents.

The second of the papers in the psychological-sociological area, "Risk Communication, Recreancy, and Organizational Effectiveness," by Lee Clarke and William Freudenburg, states that risk analyses require inputs from experts and the public. Experts are essential to the development of safe ways of handling modern technology. Their expertise is the result of study and continued practice in narrow areas. The organizations in which they work encourage and reward such specialization. However, because of their narrowness they do not see the whole picture even when they are taken as a group. On the other hand, the public is weak on details but surprisingly strong on the big picture. Experts often take the position that members of the public are ill informed and do not understand risk. The authors of the present paper state that recent research reveals the public is much better informed, even on matters of detail, than the experts believe.

The authors make another point in this area that is very important. They say that concerns about quality of life and community character issues can lead to the kind of dialogue between industry, risk specialists, and the pubic that gives rise to changes in sociotechnical systems. The result can be a much greater increase in safety than can be achieved by numerous small, technical changes in the product or the process by which it is produced. Moreover, rather than necessarily reducing profits, the involved enterprise may become more profitable.

The failures that business and government encounter in dealing with the public on issues of technology and safety often arise because members of the public are treated as ignorant. The position then taken is that a solid public relations effort is needed to properly inform the public. In this education effort, the risks of a given project are compared with familiar risks, such as those that arise in driving a car. Such approaches are bound to fail and to engender distrust because risks are not commensurable in a narrow technical sense. Clearly, this position is supported by Slovic and is illustrated in his factor space diagrams.

On how organizations tend to function, Clarke and Freudenburg refer to Herbert Simon's concept of bounded rationality. The point is made that organizations induce bias. They and their employees and other participants make systematically biased choices. They understate risk because they do not look at the broad social effects of technical breakdowns. The authors claim that organizations can come to realize that their difficulties in dealing with the public are not simply due to the public's failure to understand risk. Organizations can make choices that recognize the social fabric and respond in fundamental ways to the legitimate underlying fears of the public.

Law and Economics of Hazmat Transportation

There are two essays in this group. The first, "Risk, Loss and Liability in the Transportation of Hazardous Materials," by Marshall Shapo, provides a great deal of background on legal issues that are of great concern to shippers and carriers and to the general public. Shapo offers clear and carefully developed explanations on the goals and background of tort law, which he takes to be the study of injury, and the rules, doctrines, and policies through which the legal system deals with the problem of injury. Disputes over the kinds of losses, with particular reference to nonecomonic losses, that should enter into liability considerations are illuminated by the author. The paper deals with attitudes toward risk and a major principle of tort law: that people may choose how much risk they are willing to take, but they should not do so at the expense of others. It also takes up the issue of the effects of law on people's conduct. The basic belief exists that statute and the rules of law can regulate people's conduct. Indeed, as has already been explained by Kenworthy and others in this volume, HMTUSA was fashioned in a way that was designed to enforce greater attention to safety issues on shippers and carriers. There is a belief that fines imposed by regulatory bodies and awards in court cases can act to deter unsafe behavior.

Shapo makes it clear that there is a difference between the view of economists on negligence and the effects of accidents, and that of the law and the courts. To the economist, rational behavior involves investing in safety up to the point where the incremental cost of avoiding accidents equals the incremental cost of the accidents themselves. This approach implies that those who are exposed to accidents, as well as those that are responsible for the exposure, will take precautions. According to Shapo, courts have sometimes taken a position of strict liability. This doctrine implies that the public is entitled to maximum protection in circumstances of great risk. Basically, the position of the court is then that it is not concerned with efficiency considerations. The issue of whether the public could have taken actions that would have reduced the risks to which it is exposed does not play the same role in the courts as it does in economists' models of efficiency. Shapo suspects that the transportation of hazmats would be the kind of activity that would often involve the maximum public protection attitude on the part of the courts. Where abnormally dangerous activities are involved, the reasoning of strict liability is likely to be invoked and defendants viewed as liable even if utmost care has been taken to avoid harm. It is interesting that in a famous case involving the spill of a dangerous chemical in a railway yard that is surrounded by a residential area, Judge Posner, who is also an economist, rejected an earlier decision on this case in which the standard of strict liability was applied. Judge Posner took the position that perhaps the best use of land in the area was not for residences but for transportation and its attendant risks. Shapo asks what we can divine from this clash of opinions. His answer will not be particularly comforting to those who seek predictability from the law. Namely, the law is not predictable and those who are involved in dangerous activities must resign themselves to a significant level of uncertainty. Shapo goes on to suggest that even if strict liability is not broadly adopted as the standard in hazmat transportation, regulators and the courts may infer negligence. The idea here is that reasonable persons may conclude that injury would not ordinarily have occurred in the absence of negligence. This seems to be the position taken by HMTUSA.

Shapo ends his essay by concluding that existing liability law, for all of its faults, offers a way of avoiding systems that would be much more faulty: a completely laissez faire economy with no regulation, and the undesirable world of pervasive regulation—even of detailed microeconomic decision making.

The second paper in the law and economics area, by Thomas Ulen and Charles

Kolstad, is entitled, "The Law and Economics of Hazardous Materials Transportation: Regulating Harm by Administrative Agency and by Tort Liability." Ulen and Kolstad take a position very similar to that taken in the Shapo paper, except they state it even more strongly. They assert that the ideal way to regulate the harms from the transportation of hazmats rests on the use of government regulation and tort law. Ulen and Kolstad categorically state that there is need to rely more heavily on ex post tort liability and less on ex ante administrative regulation than is now the case. They have a way of reasoning about the problem that helps them choose between two standards of liability, negligence and strict liability, for situations that involve the transportation of hazmats. Finally, they have a theoretical model that helps them to determine when and how ex post and ex ante regulations should be combined to achieve the optimal reduction in the external social costs of accidents.

To resolve the question of whether negligence or strict liability is the appropriate standard to employ in cases involving hazmat transportation, the authors introduce the concept of bilateral precautions. These are defined as the meaningful actions both parties to a potential accident could take to reduce the probability of its occurring, or to reduce its severity. If there is really little that the potential victim can do to reduce the probability or severity of an accident, then it is not sensible to shift liability back to the potential victim. The authors believe that this is the case in the transportation of hazmats, which leads them to favor strict liability as the standard, much the way that HMTUSA is written.

Ulen and Kolstad point out that the complementary use of ex ante and ex post regulation is so widespread that the lack of persuasive theoretical arguments for their joint use is surprising. They attempt to shed light on how to achieve an optimal blend of the two forms of regulation.

In their reasoning on this subject, the authors consider two kinds of situations. In one of them, the potential wrongdoer is uncertain as to what would be the outcome of the tort process and the amount of liability that might be imposed. They conclude that in this case, ex ante and ex post policies should be used jointly. In addition, the authors conclude that efficiency requires that the ex ante regulatory standard be set at a level such that if it were used alone, a less than socially optimal level of protection would be provided. If the ex ante regulations are set at the socially optimal levels, there will be too much investment in safety. Only if there is no ex post liability, which is the same as a situation in which there is zero probability of a judgement against the wrongdoer, should ex ante regulations be put at the socially optimal level. Ex post and ex ante regulation should be used separately only if the determination of liability is perfectly certain and accurate.

The model and the reasoning concerning the advantages that follow from the complementary use of ex post and ex ante regulation are very satisfying. It is too much to ask that the authors suggest ways in which society can decide how much below the socially optimal level of regulation the ex ante requirements should be set in different circumstances. The reader is impressed with what the authors have achieved, but left with the less than satisfying conclusion that anything greater than zero and less than the socially optimal level of ex ante protection will produce the socially optimal solution with equal efficiency.

License Fees, Market Structure, and Costing

The final three papers in the volume are by economists and deal with well-defined economic issues. The first of these papers, "Annual License Fees and Other Charges for Road Transportation of Hazardous Materials," by Leon Moses and Ian Savage, deals with the issue of licensing the carriers of hazmats. The authors evaluate the flat license fee of $300 that DOT has recently imposed on motor carriers of certain kinds of hazardous materials. The purpose of the fee is to raise sufficient revenue to support the necessary level of training of enough first responders so that the nation will be able to adequately handle hazmat incidents. Moses and Savage go beyond the present fee system. Their interest is in the character of a license fee system that would contribute more than the present fee system to the achievement of social optimality in pricing accidents that involve the transport of hazardous materials.

The authors identify four categories of costs associated with truck accidents. The first of these costs are internal to a firm and cover such things as repairing trucks, health benefits for drivers involved in an accident, etc. A trucking firm has every incentive to invest in safety up to the point where its private marginal cost of achieving greater safety is just equal to the marginal benefit. They conclude that there is therefore no need to include these costs in a government-imposed license fee.

The second category of costs involves identifiable individuals who are neither shippers nor carriers. They are third-party users of the highway, or owners of property that is damaged in an incident. Along with authors of earlier papers in this volume, Moses and Savage believe that the tort system can also adequately take care of these costs.

The third category of costs involves damage to the environment and broad groups of individuals. To assure that firms have the correct incentives to provide safe operations, the full social and environmental costs of accidents should be recovered from the parties at fault.

The final category of costs that are associated with accidents involves the response to hazmat incidents by public agencies such as fire and police departments, hospitals, etc. The equipment and other facilities needed to contain and remove a spill from the site of an incident, especially when dangerous materials are involved, will require different and more expensive equipment than is normally found in a fire department. At least some full-time, highly trained personnel, rather than volunteers, are also likely to be required.

These costs differ from the variable costs mentioned above. They are in a sense fixed because the equipment and personnel have to be in a place even when there are no incidents. They are also recurrent since equipment wears out and must be replaced. These costs should be paid for from a central fund to which trucking firms and possibly shippers contribute through an annual license fee.

In their past research, the authors have found that accident rates and the severity of accidents vary considerably by size of firm, character of products the firm transports, the extent to which the firm is involved in long-haul operations, whether the firm is a common or a private carrier, etc. They use elements of this past research to show how the annual fee should be computed.

The second of the economics papers, "Costing the Movement of Hazardous Materials by Rail," by Michael Tretheway and William Waters, raises fundamental questions about costing that are ignored by most of the writers who are interested in finding ways of achieving optimal rates of investment in safety. Those writers, including Moses and Savage in this volume, proceed as if the firms that carry hazardous materials at least know their own private costs of such transport. Tretheway and Waters create doubts about whether such certainty is warranted.

The authors indicate that hazmats can affect rail costs in a variety of ways. The first involves no real difficulty. It is required that the additional costs of handling hazmats be identified and assigned directly to specific movements. The authors believe that this task can be handled.

The authors believe that hazmat movements can also influence rail costs indirectly. The movements can put constraints on rail operations. These constraints increase the costs of transporting other freight. For example, in order to avoid an area of particularly great population density, a train that is carrying hazmats may be diverted to a somewhat circuitous route. If the train is also carrying other commodities, the cost of their transport is raised. These additional costs are attributable to hazmats. Another example of indirect cost impact involves investment in upgrading track for the purpose of transporting hazmats. The track might have been perfectly acceptable in unimproved quality for the movement of other freight.

Efficient pricing of hazmat traffic requires that the true system incremental cost of the traffic be known. Problems arise because current rail costing systems are developed for "average traffic" and do not take hazmats into account. It is necessary to modify the current costing techniques so they reflect the extra demands placed on the rail system by hazmats. Those demands will vary with the nature of the hazardous material, as well as its point of origin and destination, and the nature of the routes over which it moves. The costs that may prove especially difficult to take into account are the costs of system delays in the delivery of all traffic because of hazmat accidents and spills.

Tretheway and Waters raise doubts about whether the present method of rail costing, the ICC's Uniform Rail Costing System (URCS), is up to the task of estimating systemwide incremental costs of transporting hazmats. The present system estimates costs by intermediate functions, such as yard operations, on-line operations, etc. A linear approach is adopted in estimating the costs of the various intermediate functions. The system does not appear to be suited to taking into account nonlinear, whole system interactive effects of the kind that may result from the transport of hazmats.

Failure to take system impact costs into account can result in underpricing hazmat services. Such underpricing encourages more use of these services than is socially optimal. Tretheway and Waters do not convey a sense of great confidence that these systemwide costs can be determined with a reasonable degree of accuracy using the present method of rail accounting.

The final paper in the volume, by Ronald Braeutigam and Leon Moses, is entitled, "A Test of Market Behavior in the Transport of Petroleum and Liquid Hazardous Materials." Deregulation of the motor carrier industry led to the entry of many new firms. Rate competition increased greatly. Individual carrier discounting from the rates that rate bureaus attempted to establish was both deep and widespread. Motor carriers could also frame contracts with shippers. Since the terms of these contracts were not available to the public, it is generally felt that they also fostered intense rate competition. Shippers' organizations broadly supported the new competitive environment. Estimates have been made that it saved shippers, and therefore ultimate consumers, billions of dollars. However, there are knowledgeable people in the transportation industries who believe that some large shippers use their economic power to force such low rates and/or high quality standards on carriers that carriers are unable to earn a normal rate of return on capital. In essence, the position is that some shippers have exerted a kind of oligopsony power on rates in some segments of the industry, and have depressed rates to the point where some carriers are unable to earn a normal rate of return on capital. According to this line of reasoning, these carriers cannot maintain their equipment, hire competent drivers, or train new drivers adequately, etc. As a result, these carriers may become involved in unsafe operations in the short run and be forced out of the industry in the long run.

This argument has been advanced most forcefully about the transportation of petroleum and liquid hazardous materials (P&LHM) products. Here a relatively few large shippers originate most of the traffic. There is no doubt that these firms are very large relative to the typical tank truck operator.

The Braeutigam-Moses paper sets out to empirically examine market structure in the P&LHM segment of the industry. The authors frame a structural model in which carriers are assumed to act as perfect competitors in the transport of general freight as well as in the transport of P&LHM. Shippers of the latter category of goods may act either as perfect competitors or as oligopsonists in the short run. Along with most other economists, the authors believe that the exercise of monopsony power in the motor carrier industry in the long run is not possible because existing firms would withdraw their capital from that segment of the industry and new firms would not enter it. The model in which the hypothesis is tested involves interaction between shippers and carriers. It allows for two factors that in equilibrium might affect the transport rate carriers receive.

The first of the factors is exercise of oligopsony power. If shippers of liquid products exercise such power, it should be expected that rates would be lower for the shipment of liquid hazmats than for general freight.

The second factor is that large hazmat shippers may be saddled with larger liability and cleanup costs associated with accidents than shippers of general freight. The shippers of liquid hazmats may also have to bear higher costs of cleanup and of training people to respond to accidents/spills than carriers or shippers of general freight. In such cases, it could be said that shippers of liquid hazmats have relatively deep pockets. The basic idea here is that if everything else were equal, equilibrium transport rates ought to be lower in an industry in which there are high-cost accidents and shippers bear a high proportion of these costs because they have relatively deep pockets.

Pooled data from 1985 to 1987 were used to test the model. The empirical tests fail to reveal that shippers of liquid hazmats act differently from shippers of general freight. The authors offer no support for either the oligopsony or the deep pockets hypothesis. Their empirical analysis provides insight into why there is no evidence of oligopsony power. Even in the short run, the industry supply schedules for both liquid hazmats and general freight are quite elastic. Under such conditions, there is no opportunity for the exercise of oligopsony power.

Perhaps the paper and its conclusions are not as convincing as they would have been if (1) the authors had included quality as a variable, perhaps using data for serious injuries and fatalities in the two sectors as surrogates for quality; and (2) they had found that accident rates did not vary significantly between the two sectors. On the other hand, suppose such an investigation had revealed that accident rates in the liquid hazmat sector are equal to, or even less than, those in general freight. If transport rates received by carriers in the two sectors are the same, but the liquid hazmat carriers provide what is effectively a higher quality service, doesn't it become more difficult to reject the oligopsony hypothesis as an adequate description of short run market structure? The word "effectively" is used above because accidents that involve liquid hazmats are much more likely to cause serious injuries and fatalities than those that arise in the transport of general freight.

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DISCLOSURE, ENFORCEMENT AND COMPLIANCE: A SHIPPER'S PERSPECTIVE ON COMPLIANCE

Don A. Boyd

Introduction

Recent legislation and rulemakings have made radical changes in the transportation of hazardous materials. The Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA), the Sanitary Food Transportation Act of 1990 (SFTA), DOT Docket HM-181 (Performance-Oriented Packaging Standards [POP]) and Docket HM-126C (Emergency Response Communication) make the shipping and handling of hazardous materials more complex and detailed than ever before. Many of the ground rules that were in effect in the past have been amended or changed. If persons involved in the transportation of hazardous materials want to continue to be involved, they must become familiar with and comply with the new laws and rules. If they fail to do so, they will face great risks and difficulties and may even be prohibited from engaging in such transport.

The task of discussing, even in a superficial manner, the many changes that the new laws and regulations make in the areas of disclosure, enforcement and compliance from a "shipper's perspective" is a complex one. However, this paper will briefly discuss some compliance and enforcement matters in the new laws and regulations from primarily a shipper's point of view.

HAZARDOUS MATERIALS TRANSPORTATION UNIFORM SAFETY ACT OF 1990 (HMTUSA)

This new law is the first major revision of the Hazardous Materials Transportation Act (HMTA) in 16 years and was precipitated by an increasing public awareness and concern about the 500,000 shipments of hazardous materials that move each day in the United States. The prior law was a short, relatively simple statute that vested primary authority in the secretary of transportation for implementation and regulation of HMTA. The responsibilities under HMTA were largely administered by DOT's Research and Special Programs Administration (RSPA). The new law (Public Law 101-615, November 16, 1990) has some 34 pages and contains provisions concerning preemption, highway routing, registration, response training, motor carrier safety permits and increased penalties for violation of law and regulations. The law is somewhat unique because of the many rulemakings and studies (fifteen rulemakings and six studies) it requires and the prescribed timetables for institution of the rulemakings and the issuance of final rules.

Many of the new or amended regulations that will result from the rulemaking proceedings will affect the hazardous materials shipper, but until the specific requirements are known it is difficult to predict with any precision which areas will have the most impact on shipper compliance with the regulations. It is quite obvious, however, that several of the provisions of the new law will require modifications, changes and additions to shipper hazmat compliance programs.

Preemption

The new law addresses in a general way some of the problems that arose under HMTA in the area of inconsistency of state and local laws and regulations with the federal regulations. The new law provides that many state and local laws involving hazardous materials transportation are preempted if they are not "substantively the same" as federal laws and regulations. The law also streamlines and simplifies the DOT inconsistency ruling process.

States may still establish highway routes provided they are promulgated in accordance with federal standards to be issued by DOT. If two or more states are involved in a routing matter the state routing requirements must not "unreasonably burden interstate commerce." This test may be somewhat difficult to apply in view of the DOT's reluctance in the past to deal with "burden" on interstate commerce. Shippers have been concerned about state and local fees for hazardous materials transportation and the new law provides that such fees must be "equitable." However, the new law provides no guidance or procedures for determining the line between "equitable" fees and those that are not.

Insofar as compliance is concerned, the general provisions of the law concerning preemption should ease shipper and carrier fears concerning compliance with two or more sets of hazardous material regulations (one set of rules in the technical areas is much better) but specific requirements that will have an impact on a shipper's operation will not be clearly defined until the final rules are issued.

Training

The training requirements of HMTUSA are an example of legislative rulemaking. HMTUSA will require shippers ("hazmat employers") to train their "hazmat employees" safe loading, unloading, handling, storing and emergency response to accidents involving hazardous materials. Documentation and certification that hazmat employees have been trained and tested in the areas of the employee's responsibility will be required. The requirements will entail additional recordkeeping for shippers. The prescribed areas for training and testing will go beyond what most hazardous material shippers now do. An issue that is created by the new law is the exact identity of "hazmat employers" and "hazmat employees." The definition of a "hazmat employee" as one who "directly affects" hazardous material transportation safety is not very precise. For example, does this include package reconditioners, testers, or drum or tank car manufacturers?

Even though there are a large number of hazmat shippers in the United States, most of them, particularly the larger ones, can probably institute new training programs and procedures to comply with the new rules. However, when the many distributors, jobbers, agents, wholesalers, forwarders, brokers and second- and third-tier shippers are taken into consideration, it is somewhat doubtful that such parties will even be aware of all the regulations. It will be a time-consuming process to spread the word about the new rules, and during the interim there may be substantial noncompliance with the new training requirements.

Registration

Most shippers and carriers of hazardous materials will be required to register at least once every five years and to pay an annual registration fee of $250 to $5,000. (Note: Since the presentation of this paper DOT's HM-208 became effective Aug. 31, 1992. The final rule provides for annual filing and a $300 fee.) Such registration should not present a compliance problem to most shippers if the rules to be promulgated are relatively simple and renewal and frequency requirements are reasonable. It should be noted that registration requirements appear to apply to both foreign and domestic companies and that DOT is given the authority to require other persons to register. The law provides that entities that are engaged in more than one activity that requires registration will be required to register only once. However, it appears that entities with several domestic and foreign subsidiaries or affiliates will be required to register each activity separately.

Knowingly

Under the prior HMTA, DOT could impose civil penalties against persons who "knowingly" committed acts in violation of HMTA or the regulations issued thereunder. The new law enhances and clarifies DOT's authority to impose civil penalties and provides that "knowing" violations of HMTA, regulations or orders issued will constitute the basis for the imposition of civil penalties.

Under the prior law, "knowingly" was not defined. However, the law now defines "acting knowingly" to be if: (1) a person has actual knowledge of the facts giving rise to the violation, or (2) a reasonable person acting in the circumstances and exercising due care would have such knowledge. The new definition of "knowingly" is intended to negate any inference that the term only encompasses actions based on actual knowledge or reckless actions. The reason for the change was a U.S. district court case that held that the secretary must prove "willful negligence" rather than mere negligence in proving a violation of HMTA (*Southern Railway Corp. v. Riley*, No. C84-1990 A, [N.D. October 10, 1986].

Pursuant to the new definition, DOT will be able to seek civil penalties for actions or omissions that are negligently committed as well as for those committed with actual knowledge in violation of HMTA or orders or regulations issued under it. The new law makes it easier to establish violations of the civil penalty provision of HMTA and should increase the motivation to comply with the law and regulations.

DOCKET HM-181: PERFORMANCE-ORIENTED PACKAGING

Almost all shippers supported the objectives of Docket HM-181, Performance-Oriented Packaging Standards (POP). The docket is designed to simplify and reduce the volume of hazardous materials regulations, reduce the need for exemptions and promote flexibility and technological innovations in packaging. The requirements of HM-181 will finally have an impact on many areas of hazardous materials transportation but several areas are of significant importance to shippers.

The new rules radically modify the regulatory scheme for hazmat transportation from one based on specifications (i.e., engineering) packaging standards to one based on performance-oriented standards. Under the new rules a shipper may use any package which meets performance criteria. While this change reduces the volume of regulations and provides for flexibility in hazardous materials packaging, it also increases shipper responsibility. Under the requirements of HM-181 it will be more difficult for a shipper to determine that a hazardous materials package complies with the regulations. Under POP "testing," compliance will be governed by whether manufacturing meets specifications. One consequence of this change will probably be an increase in litigation over injuries and damages arising out of an exposure to hazardous materials, with the court system playing a greater role in compliance.

Testing as a tool to determine compliance with the regulations raises other new shipper considerations. Under the prior system a shipper could in most cases rely on a manufacturers certification that the package was manufactured in accordance with DOT specifications. Under the new system, an incident or spill may trigger a DOT investigation. If DOT (or an injured plaintiff) tests the shipping package and obtains different results than the shipper/container manufacturer—as might occur through different testing methods or interpretation of test procedures—a violation may be alleged. The shift to POP standards, and the inherent flexibility of the system, imposes upon a shipper a greater burden than that held in the past under HMTA, especially in the area of risk management. A shipper should establish an effective compliance program of:

- Comprehensive review and assessment of the regulations and determination of the steps needed to comply

- Documentation of those assessments

- Careful selection of qualified package vendors and testing laboratories

- Training of employees

- Notice to potentially affected third parties, including distributors, customers, and warehousemen

- Inspection and auditing, both internally and of outside vendors

It is critical, for any compliance program, to maintain a proper and complete paper trail, including detailed operating and training procedures to effect the necessary compliance.

Performance-oriented standards set only minimum packaging requirements. Thus, in the event of a package failure, a shipper could be held liable in an action alleging failure to utilize packaging that exceeds the minimum.

Transition

DOT in HM-181 provided for several transition periods for various parts of the new rules. The rule as a whole became effective October 1, 1991. However, shippers were permitted to operate under the new standards on January 1, 1991. Other transition periods for up to five years are permitted for continued use of specification packages or continued manufacture of packaging that will be rendered obsolete. During the transition periods shippers have the option of using the packagings authorized by the old specifications or the new performance-oriented packagings. Even though the transition period allows the continued use of specification packaging, a problem arises if current packaging does not meet or satisfy the performance goals. For shippers, a potential liability issue is presented when specification packaging continues to be used during the transition period with the knowledge that such packaging may not or will not be permitted in the future.

Enforcement

The preamble to HM-181 contains a brief explanation of how DOT will proceed with enforcement of the new rules. DOT states that "the most important determinant of the qualifications of a package will be how well it performs under test conditions." It should be noted that DOT concern is with "test conditions" rather than "transportation conditions." Enforcement will continue to include random packaging inspections by DOT inspectors at freight terminals, intermodal transfer facilities, airports and other facilities to determine compliance with proper marking and packaging. However, DOT's new cornerstone for enforcement will be testing nonbulk packaging for compliance. It is also DOT's stated intent to focus its inspection efforts on packaging manufacturing facilities and testing facilities and shipper's facilities where manufacturing operations are performed. The new inspection efforts will cover:

1. Review of packaging manufacturers and shipper's test records

2. Observation of tests performed by shippers and manufacturers and third party test agencies
3. In some cases, tests of packaging by or on behalf of DOT

In view of the stated DOT efforts, shippers and package manufacturers will need to develop and follow programs that carefully document, store, and permit easy retrieval of all relevant data on package tests. Since "testing" will be the cornerstone of the DOT enforcement program, shippers and package manufacturers should also be aware that failure of a package will be considered *prima facie* evidence of a violation of the regulations.

The preamble to HM-181 states that the development of an enforcement program will be an "evolutionary process." This is not particularly different from most enforcement programs for new laws and regulations which tend to develop and change in accordance with changing conditions and circumstances. However shippers and other persons concerned with complying with the regulations should be aware that there is in most cases a thin and often indistinguishable line between an "evolving" enforcement program and a program that experiments with various methods and theories at the expense of persons who are the test subjects. Shippers should be concerned that because of the generally imprecise nature of performance- oriented standards there may well be many significant inconsistencies in enforcement cases, especially when consideration is given to the different modal administrations within DOT and the many state enforcement agencies that will be involved in the enforcement of HM-181 rules.

Significant Release

Prior to the promulgation of HM-181, section 173.24(a)(1) provided that packages should be designed, constructed, maintained, filled and closed so that under conditions normally incident to transportation there would be no "significant" release of hazardous material to the environment. Initially it was proposed to delete the word "significant" which would have allowed for no release. In response to a number of comments filed in this docket, the final rule does delete the word "significant" but in its place substitutes the word "identifiable" (without the use of instruments) [section 173.24(b)(1)]. No explanation is given concerning the interpretation that will be used for "identifiable" but in view of the change the use of the word "identifiable" is probably more restrictive. It may be some time before shippers will know how DOT will interpret "identifiable," and it will probably require a court decision before shippers can be certain what the word means.

Shipper/Manufacturer Responsibility

Under HM-181 DOT takes the position that determining the suitability of packaging is essentially a shipper responsibility. The shipper is responsible for making certain that a package is assembled, closed or otherwise prepared for transport in full compliance with the specification or standard under which the package was manufactured, including any condition for use set forth by the manufacturer. The regulations require that a manufacturer or subsequent distributor of packaging inform each person to whom the packaging is transferred of any specification requirements which have not been met at the time of the transfer.

In response to shipper concerns raised in comments, DOT attempted to explain the responsibilities the new rules place on shippers and packaging manufacturers. It is stated in the preamble that shippers will not be held responsible (under enforcement procedures) for package failures due solely to manufacturers' noncompliance with the regulations, and that manufacturers will not be held responsible for violations caused solely by shippers. While this is a very simple explanation and may sound easy to enforce, it is not very reassuring to shippers, because in the real world it is usually quite difficult and sometimes almost impossible to determine the sole cause of a package or container failure. In most cases there are a number of factors that may or may not contribute to a package failure. In those cases where there is no single cause for the failure it may result in a case of joint responsibility for the shipper and package manufacturer.

Compliance Responsibility

Section 173.22(a)(3) of the regulations currently provides that a shipper may rely on the markings of a packaging manufacturer to meet the shipper's responsibility to assure that only complying packaging is utilized. While this provision has not been changed, a new section 178.601(b) provides that "it is the responsibility of the packaging manufacturer and the shipper, to the extent that assembly functions including final closure are performed by the latter, to assure that each package is capable of passing the prescribed tests." This provision clearly imposes responsibility for compliance with the performance criteria upon the shipper, since the shipper, or the shipper's agent, will be the party who fills the package and effects final closure. Therefore, in most cases a shipper should not rely on the packaging manufacturer's tests, but must take such steps as are necessary to make certain that the package being used for hazardous materials meets performance standards.

Minimum Requirements

At several places in the explanation of HM-181 (section 178.601(a); section 171.8—definition of packaging) it is stated that the test procedures to ensure that packages of hazardous materials can withstand the normal conditions of transportation are considered "minimum requirements." The use of such words indicates there is no prohibition against performing additional tests or exceeding the prescribed packaging standards. The use of the words "minimum requirements" adds little if anything to the regulations, but shippers and other persons subject to the regulations should be aware that the use of such words is an open invitation for plaintiffs in tort litigation to assert that mere compliance with "minimum" requirements is less than safe and may constitute negligence. In this context, if the "minimum" requirements prescribed by RSPA are less than safe the argument could also be made that RSPA has failed to discharge its prescribed statutory duties and responsibilities.

DOCKET HM-126C - EMERGENCY RESPONSE COMMUNICATION

After three attempts (June 27, 1989, January 10, 1990, and August 17, 1990) the new requirements proposed in Docket HM-126C became effective December 31, 1990. In general, the new rules prescribe requirements for additional emergency response information on shipping papers and packages and also require the maintenance of emergency response information on transportation vehicles and at transportation facilities. Other provisions of the final rule require technical names of products be included in the description of the materials on shipping papers with n.o.s. (not otherwise specified) descriptions and the maintenance of a 24-hour telephone number to answer detailed response questions.

While the new rules will affect all persons involved in the preparation and transportation of hazardous materials it is quite apparent that the primary burden will fall on the shipper of hazardous materials (a person who offers). As far as carriers are concerned, they are only required to ensure that the required information is immediately available when the hazardous materials are offered for transportation and that such information is made immediately available to personnel who respond to an incident or conduct a hazardous materials investigation.

In general, the new rules provide for two types of emergency response information. The first is the information which must be immediately available either on or in association with the shipping papers at all times when hazardous materials are present. These requirements (section 172.602) could be called the minimum initial responder information. A second type of information required by the new rules, comprehensive product-specific emergency response information, must be immediately available from a person who is contacted through the shipper-provided emergency response telephone number which is placed on the shipping paper (section 172.604).

Initial Response Information

The minimum information that must be made available to initial responders at the scene of an accident includes the following:

1. The description of the hazardous material
2. Immediate hazards to health
3. Risks of fire or explosion
4. Immediate precautions to be taken in the event of an accident or incident
5. Immediate methods for handling fires
6. Initial methods for handling spills or leaks in the absence of fires
7. Preliminary first aid measures

This information must be in English and be available for use away from the package of hazardous materials and may be supplied in three alternative ways. It may be: (1) on the shipping paper; (2) in another document if that document provides the basic description (e.g., a Material Safety Data Sheet [MSDS]); or (3) in two documents, the shipping paper and another document, such as the *Emergency Response Guidebook* (ERG), as long as the two are cross-referenced to each other.

While it appears that DOT has allowed significant flexibility for compliance with the minimum responder information, there are a number of matters that should be considered in reaching a decision of which method to use. It is quite apparent that method number 1 (on the shipping paper) will not be practical for most materials because it would result in a large amount of information being placed on shipping papers. This would be especially true when several materials are consolidated in one shipment. Alternative number 2 could result in a large number of documents being attached to the shipping paper, especially where technical names are required.

The third alternative may provide a shipper with the most flexibility for compliance and be the easiest to use as long as the separate document provides information that is related to that on the shipping paper (such as ID number and proper shipping name). Many shippers will probably use either a MSDS or the DOT *Emergency Response Guidebook.*

24-Hour Telephone Number

The new requirements provide for the maintenance of a 24-hour emergency telephone number to provide product specific information for mitigation of the consequences of an incident (section 172.604(a)). This telephone number must be:

1. Monitored at all times while the hazardous material is in transportation, including storage incidental to transportation

2. The number of a person who is either knowledgeable of the hazards of the material being shipped and has comprehensive emergency response and incident mitigation information for the material, or has immediate access to a person who possesses such knowledge and information

3. Entered on the shipping paper in a clearly visible location immediately following the hazardous material description

The person offering the hazardous material may use the telephone number of another agency if that agency is capable of providing the required information concerning the hazardous material and if that agency has accepted the responsibility for providing the information. The shipper must also ensure that the agency has current information concerning the hazards and characteristics of the hazardous material being shipped.

There are several important areas that should be considered when developing a compliance program to meet all the provisions of HM-126C. It is quite probable that questions will arise concerning the interpretation that will be placed on some of the specific words used in the rules. One question might concern whether the required information is "immediately" available. Immediately probably means almost instantly with little or no intervening time lag. It also may be difficult to determine whether the information furnished is of the kind and type that "can be used to mitigate a hazardous materials incident" (Section 172.602(a)). When rules and regulations use such words as "at a minimum" and "comprehensive" the possibility of either a broad or a narrow interpretation by the regulators or the courts places a heavy burden on those attempting to comply with the regulations. To comply with new rules also requires efforts by shippers to devise the most practical and cost efficient methods that may be used to achieve compliance.

Some Suggestions - HM-126C

If a shipper decides to use an outside agency to meet the requirements of section 172.604(a), the shipper should, at a minimum: (1) have a written agreement of the services the outside agency will provide, and (2) for each hazardous material that is shipped, keep a copy of the "comprehensive emergency response and incident mitigation information" that is supplied to the agency. Also, the shipper should obtain a written acknowledgement from the outside agency that it has received the information and accepts the responsibility for providing the information as required by section 172.604(a). It would also be prudent, though probably difficult, to obtain a statement from the agency that the shipper will not be subject to any enforcement or civil liability that results from the failure of the agency to furnish the required information.

It should also be noted that although DOT cites MSDS's and emergency guidance manuals as examples of possible ways to meet the requirements of section 172.604, this does not mean that the use of such documents results in automatic compliance with the rules. The preamble to HM-126C states that DOT has not required nor prohibited the use of an MSDS as a means of providing the information, but DOT also states that "no single standard exists for the preparation of MSDS's to provide emergency response information and . . . the MSDS may not, in all instances, provide specific information relative to response actions to be taken during transportation related incidents." (*Federal Register*, June 27, 1989, p. 27142).

Therefore, MSDS's may or may not meet the requirements of section 172.604(a) and use of the MSDS will not assure automatic compliance with the requirements. If an MSDS is used it must be reviewed to make certain that it contains the specific information about the "hazards and characteristics of the hazardous material being shipped," and the "comprehensive emergency response and incident mitigation information for the hazardous material."

An alternative to the use of an MSDS is the ERG. It should be noted that the preamble to the final rule states that DOT has not imposed a requirement that the ERG be carried on each transport vehicle and be available at facilities involved in the transportation of hazardous materials. From a study of the new rules and the DOT explanation it appears that in general the ERG can be used to meet the requirements of section 172.602(a). However, use of the ERG does not assure automatic compliance with the regulations. Shippers are not relieved of their responsibilities by only requiring a carrier by contract or letter to have copies of the ERG on vehicles. If the ERG is used, the person offering the hazardous material for transportation must ensure that the ERG is properly maintained and should check to make certain that the information required by section 172.602(a) is in fact in the ERG at the time the material is offered for transportation. It appears that the objective of the rule is similar to the one addressed in section 172.506, which requires a person offering hazardous materials to provide the required placards to a motor carrier unless the motor vehicle is already placarded.

If a shipper is only concerned about enforcement of the HM-126C requirements it is probably sufficient to rely on the use of the ERG for compliance with section 172.602(a). In the area of civil liability, however, the argument may be less persuasive. The automatic use of the ERG without determining that the applicable pages adequately cover the hazards of the material and provide the appropriate information may not be enough. Even though the final rule makes frequent mention of the ERG as a potentially satisfactory document, shippers should not be lulled into a false sense of security and believe that the use of the ERG will be a solution to all compliance matters.

Some Problems - Compliance

The requirements of HM-126C present a number of problems for hazardous materials shippers. One problem discussed in the preamble of the final rule (August 22, 1990) concerns the applicability of the rule to import/export shipments. The Ocean Carrier Dangerous Goods Coalition took the position in comments filed with DOT that many shippers in U.S. foreign commerce cannot or will not comply with the emergency response information (including the 24-hour telephone number) requirements. They state that the involvement of non-vessel-operating commercial carriers (NVOCCs), forwarders, brokers, trading companies and consolidators makes the task of providing the required information difficult if not impossible. However, in the final rule, DOT declined to make changes or exceptions for import shipments.

Some rail shippers may have difficulty complying with the HM-126C requirements at switching locations, leased side track locations and loading/unloading tracks that are off plant at isolated, unmanned locations. Such locations have the potential for not having guidebooks and shipping papers present at all times. It will be incumbent upon the operators of such locations to develop plans, programs and procedures for compliance with the emergency response information requirements. In some cases it may be necessary to develop alternate supply and shipping patterns or to abandon such remote storage locations.

To achieve compliance with the requirements of HM-126C will require consideration of a number of factors. Appendix A is a sample checklist or standard which illustrates some of the more significant matters that should be considered in developing a compliance program. Appendix B sets forth some DOT answers to questions concerning interpretation of the HM-126C requirements.

Appendix A - A Brief Checklist for HM-126C

When a shipper is considering developing a compliance checklist or standard there are many things to be considered. The following is a brief list, not all inclusive, of matters that should be considered in order to attempt to assure compliance with HM-126C.

1. <u>Emergency Response Telephone Number</u>

   Should be printed on all shipping papers, including but not limited to domestic bills of lading, ocean bills of lading, air waybills and any other documents used for transportation.

   Contracts with carriers (rail, motor, consolidators, NVOCCs) should clearly show that even where the carrier may be the shipper, it is the primary shipper or manufacturers who should be contacted and this must be clearly indicated on the shipping document.

   If a third party is used as the information source, be certain that all relevant information (MSDSs) has been given to the party and that provisions have been made to update the information at appropriate intervals.

   As part of the purchase order, all vendor products that will be reshipped in either a vendor's name or shipper's name should contain a request for the vendor to supply the required information and update it periodically.

A vendor of hazardous materials should be encouraged to register with a third-party information source.

The product or trade name used on an MSDS must appear on all shipping papers after the hazardous material so the MSDS can be quickly located.

MSDSs for imported materials should be provided before the material is imported into the United States.

Provision must be made for one-time (emergency samples) shipments so the response information requirements will accompany the shipments.

2. Technical Name of NOS - Proper Shipping Name

The shipper should provide the technical names of the hazardous ingredients for all proper shipping names as listed in section 172.203(k) and such information should be placed on shipping papers and packages immediately following the proper shipping name.

3. Emergency Response Information

(If the third option is used—another document cross-referenced with and accompanying the shipping paper).

For truck shipments use DOT's *Emergency Response Guidebook.*

For rail shipments use AAR's *Emergency Handling of Hazardous Materials.*

For air use ICAO's *Emergency Response Guidance for Involving Dangerous Goods.*

For ocean shipments use IMO's *Emergency Procedures for Ships Carrying Dangerous Goods* (EMS)

As a general rule MSDSs will not be given to carriers but will be given upon request.

4. Means of Compliance

Truck drivers should make sure that the latest ERG is in their possession. This fact should be documented in some way, perhaps with a statement of the bill of lading.

A supply of ERGs should be maintained at all shipping locations.

The 49 STCC numbers should be added to all shipping descriptions for rail shipments.

Contracts with carriers should require that drivers will have an ERG in their possession at all times.

Contracts with air and ocean carriers should provide for appropriate ICAO or IMO guidebooks aboard planes and ships.

Rail contracts should require that STCC codes will comply with the DOT emergency response requirements.

All shipping locations should carefully check the ERG, AAR, ICAO and IMO guides to make certain the information concerning the products shipped from that location is correct.

Appendix B - Some DOT Responses to HM-126C Questions

1. What is meant by the term "immediate access" as specified in section 172.604(a)(2), in determining whether emergency response information is immediately available, as required by section 172.600(c)(1) and (2)?

The intent of the phrase "immediate access" means accessibility to someone having comprehensive emergency response information without undue delay. Section 172.604(a)(2) requires that the person answering the phone be able to provide detailed information for the material being shipped or able to connect the caller to a person who has that knowledge without undue delay.

Specific information must be available that goes beyond the kind of information initial responders must have available to them. The specific information requirement includes such things as: flash point; toxicity data; boiling point; vapor density; specific gravity; solubility; miscibility; water reactivity; flammable limits; odor; physical state—gas, liquid, or solid; and detailed medical information). Information that may be needed to perform such functions as long term clean-up procedures may be available through subsequent contacts, (i.e., the offerer of the material rather than the organization providing the "immediate information").

2. Would the following scenarios comply with the requirements of section 172.604(a)(2)?

A. The person answering the phone is knowledgeable and can provide comprehensive response and accident mitigation information for the material that is the subject of the call.

The answer is yes.

B. The person answering the phone is not knowledgeable of the hazards and characteristics associated with the hazardous material, but has immediate access to a person who has such knowledge and is able to"patch" the caller through to the person who can provide the information. In using the "patch" method, at what point would compliance be accomplished?

The answer is yes. Use of the "patch" method to connect the caller with the person providing the emergency response information without undue delay would satisfy the requirement in section 172.604(a)(2).

C. The person answering the phone has no knowledge of the hazards and characteristics of the hazardous material or comprehensive emergency response information, and merely provides another number or numbers to the caller of a person who is knowledgeable.

The answer is no. Merely providing another telephone number, without providing the required response information or connecting the emergency responder to a knowledgeable person, does not fulfill the requirements in section 172.604. See response to first question.

D. The person answering the phone has no knowledge of the hazards and characteristics of the hazardous material or comprehensive emergency response information, gets the number of the caller and then has the knowledgeable person return the call.

The answer is no.

E. The person answering the phone is not knowledgeable of the hazards and characteristics associated with the hazardous material, is unfamiliar with the terminology, subject matter, and the information provided to him, and simply reads the information to the caller.

The answer is no.

3. If another agency's telephone number is used as provided in section 172.604(b), does merely providing a telephone number and name of a person within a shipper's company constitute compliance with this provision?

The answer depends on whether the agency has immediate access to and can connect the caller to the person within the shipper's company who can provide the required comprehensive information, as described in the first response.

4. Does the description, "Flammable liquid, corrosive, n.o.s. (contains methanol, potassium hydroxide), UN2924," comply with the shipping paper requirements in section 172.202(a)(2)?

> The answer is no. The correct description is, "Flammable liquid, corrosive, n.o.s. (contains methanol, potassium hydroxide), flammable liquid, UN2924." If a proper name contains words describing more than one hazard class, the hazard class of the material must be included in the basic description after the proper shipping name.

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COMPLIANCE AND ENFORCEMENT PROBLEMS IN HAZMAT TRANSPORTATION: WILL THE HAZARDOUS MATERIALS TRANSPORTATION UNIFORM SAFETY ACT OF 1990 MAKE A DIFFERENCE?

William E. Kenworthy

In adopting the Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA),[1] Congress made a finding that "accidents involving the release of hazardous materials are a serious threat to public health and safety." The various remedial actions required under the act, including the strengthening of the civil and criminal enforcement provisions, clearly reflect a perceived need to strengthen hazardous materials enforcement and to more closely monitor the fitness of motor carriers transporting hazardous materials. The ultimate goal of safe transportation of all hazardous materials shipments from origin to destination is one with which there can be no quarrel. Whether the measures that Congress adopted are suitable, or even likely, to advance that goal is a question that deserves close attention. The U.S. Department of Transportation (DOT) faces a number of very serious questions in its efforts to flesh out the act by the several rulemakings that are required.

REGISTRATION OF SHIPPERS AND CARRIERS

The first part of the puzzle is that today no one really knows what carriers are transporting hazardous materials or how many such carriers exist. Knowledge as to the universe of shippers is totally inadequate. The congressional findings in the act refer to DOT estimates that approximately 4 billion tons of regulated hazardous materials are transported each year and that approximately 500,000 movements of hazardous materials occur each day. These are only estimates, however, and no one knows for sure. Moreover, those who are shipping and transporting these substances are not fully identified.

The Interstate Commerce Commission (ICC), the licensing authority for interstate common and contract carriers of property, does not know how many common and contract carriers of property have operating authority that includes hazardous materials in whole or in part, how many of those are still operating, or how

1. 1 P.L. 101-615, 104 Stat. 3244, to be codified at 49 U.S.C.App. 1801, et seq.

many are actually handling hazardous materials.[2] This in itself is troubling, since the level of public liability insurance required by 49 CFR 1043 is affected by the type of hazardous materials handled. The universe of potential carriers becomes far larger when private carriers are taken into account. DOT's current estimates indicate that the number of interstate motor carriers in the U.S. exceeds 200,000, but there is no way to determine how many of those firms transport hazardous materials.

The information void is even greater when one asks about the shippers of hazardous materials. Some shippers, such as a duPont or Union Carbide, are highly visible, but thousands of others are virtually anonymous. A recent General Accounting Office (GAO) report to Congress found that this lack of basic information hindered DOT in its hazardous materials enforcement efforts.[3] That report addressed only rail enforcement but observed:

> The inspectors we spoke to had various ways of identifying new hazardous materials shippers such as checking telephone directories, reviewing waybills, asking railroad staff, and reading newspapers. Also, several said they identified shippers by simply driving around the area and noting any new companies that appeared to be involved in hazardous materials products. In our view, however, these methods are not systematic and would not ensure that all hazardous materials shippers are identified. In particular, small and seasonal shippers would be likely to remain undetected. One hazardous materials specialist told us that such shippers may be more likely to have safety problems than large, well-known shippers that can afford to train personnel to handle hazardous materials as the regulations require.

If the problem is that serious with rail shippers (and it is), the dimensions of the problem as related to shippers by motor carriers are unimaginable. There can be little doubt that widespread registration of shippers, carriers and those involved in packaging will improve compliance and enforcement by identifying those who are subject to the regulations.

Ever since the Hazardous Materials Transportation Act (HMTA) became law in 1975, DOT has possessed the authority to require registration by all shippers of hazardous materials and by all who are involved in the manufacture, repair, testing or sale of packaging materials or containers for such substances.[4] However that authority was never exercised, except with respect to shippers of flammable cryogenic materials.

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2. Ex Parte No. 55 (Sub No. 69A), Rules Governing Applications for Operating Authority, Revision of Form OP-1 (Hazardous Materials), decision served April 13, 1990 (slip op.)

3. Railroad Safety: DOT Should Better Manage Its Hazardous Materials Inspection Program, GAO/RCED-90-43, Nov. 1989.

4. 49 U.S.C.App. 1805.

HMTUSA addresses this problem by commanding DOT to require registration by shippers and carriers of the most hazardous commodities, and to consider through rulemaking whether others should be required to register. The registration process is in part a revenue raising device, designed to create a fund for training of first responders, but it will also go a long way toward filling fundamental gaps in our knowledge about the extent of hazardous materials transportation in the United States. Section 8 of HMTUSA amends the act by requiring the registration of all who transport or cause to be transported:

1. Highway route controlled quantities of radioactive material
2. Shipments of more than 25 kg. of classes A or B explosives
3. Materials designated as extremely toxic by inhalation, in quantities of more than one liter per package
4. Any hazardous material in a bulk package, tank or container with a capacity of 3,500 or more gallons or 468 cubic feet
5. Any hazardous material in a shipment of 5,000 pounds or more and requiring a placard

The agency's authority to require registration by others includes all persons in the packaging and container industry. The secretary must conduct a rulemaking to determine the content and form of this registration program in time for the first registration, which is to take place by March 31, 1992, or September 30, 1992, at the latest.

As previously noted, the registration program has a dual purpose. The first is to create a fund from which first responders may be trained. The second is to remedy the lack of knowledge about who is involved in hazardous materials transportation, so that enforcement efforts can be properly directed. Neither goal is limited to those categories of shippers or carriers for whom registration is mandated, as listed above. Therefore, in the rulemaking process sound policy would seem to require casting the registration requirement quite widely.

For example, enforcement would be easier if registration were required of all shippers of hazardous materials in placardable quantities. Why Congress selected a cutoff point at 5,000 pounds is not explained in the legislative history, and there is no obvious rationale for that number. Moreover, registration should be required of all entities engaged in package or container manufacture, testing or reconditioning. Such registration will become more important in view of the transition to performance-oriented packaging under the Docket No. HM-181 regulations. The identification and registration of those engaged in this aspect of hazardous materials transportation will be an important step in ensuring packaging integrity.

Enforcement of the registration requirement can be largely self-executing if DOT accompanies the registration process with the issuance of a registration number. DOT could then require the registration number to appear on all shipping documents, and carriers could be prohibited from accepting a shipment from an unregistered shipper. Conversely, shippers would be prohibited from tendering a shipment of hazardous materials to an unregistered carrier.

The rulemaking that implements this section, as well as others in HMTUSA, will require DOT to determine which substances are extremely toxic by inhalation. DOT has the foundation for dealing with this issue by its new regulations adopted under HM-181.[5] Division 6.1, poisonous gases, are assigned to Hazard Zones A through D, depending upon the volatility and toxicity of the gas, i.e. the number of test rats it kills. DOT must now determine which Hazard Zones correspond to the statutory criteria as "extremely toxic by inhalation." One further question which I believe should be resolved in that process is whether these rules should apply not only to highly toxic gases, but also to other substances that may emit toxic gases in a fire.

PERMITS FOR MOTOR CARRIERS OF HAZARDOUS MATERIALS

HMTUSA breaks new ground by providing for DOT to issue hazardous materials transportation permits for motor carriers. It is ironic that ten years after the Motor Carrier Act of 1980, by which Congress created a system of basically open entry into the motor carrier field, Congress has now established DOT as a gatekeeper for the field of hazardous materials, limiting entry to those determined to be fit for this purpose. Section 8 of the act amended 49 U.S.C. 1805 by requiring motor carriers transporting certain hazardous materials to receive a safety permit from DOT and to keep proof of that permit in all vehicles used to provide such transportation. This new permit will be required, as a minimum, for transportation of the following categories of shipments:

1. Class A or B explosives
2. Liquefied natural gas
3. Material designated as extremely toxic by inhalation
4. Highway route controlled quantities of radioactive material

The secretary may expand this list by rulemaking. The act requires the secretary to establish rules for this permit program, including application forms and criteria, within one year. Permits will be required in November, 1992, two years after the date of enactment. Interestingly, the act makes no provision for the issuance of grandfather permits, since there is no constitutional right to be an unsafe transporter of hazardous materials.

The rulemaking to be conducted by the secretary also must further define the standard of fitness. At a minimum the act requires the secretary to find that the carrier is fit, willing and able:

(A) To provide the transportation to be authorized by the permit;

5. 55 Fed. Reg. 52,402, 49 CFR 173.132.

(B) to comply with this title and the regulations issued by the Secretary to carry out this title; and
(C) to comply with any applicable Federal motor carrier safety laws and regulations and any applicable Federal minimum financial responsibility laws and regulations.

The regulations also must spell out the circumstances and procedures under which a permit may be suspended or revoked. The secretary may revoke, amend or modify a permit after notice and an opportunity for hearing. A permit may be revoked forthwith in the event that the carrier's operations pose an "imminent hazard" to public safety, in which event the carrier will receive only a post-revocation hearing.[6]

Given the short time frame within which DOT must establish the parameters of this permit system and make findings that carriers are "fit, willing and able" to undertake the transportation of hazardous materials, DOT is likely to employ the safety ratings now issued by the Federal Highway Administration (FHWA) as threshold evidence of fitness and safety. However, the safety rating system needs substantial overhaul and improvement if it is to fill that key function.

Reliance upon FHWA's safety rating system to determine fitness for the transportation of hazardous materials is also mandated by the Motor Carrier Safety Act of 1990, which was adopted in the waning days of the 101st Congress as Section 15 of H.R. 3386, the Sanitary Food Transportation Act of 1990 (SFTA), better known as the garbage backhaul bill.[7] Section 15, which amended the Hazardous Materials Transportation Act, received relatively little attention when it was passed, because public attention was focused on the controversy over the budget. As pertinent here, the act provides as follows:

SEC. 117. UNSATISFACTORY SAFETY RATINGS

(a) Prohibition on Transportation.—Effective January 1, 1991, if a motor carrier receives a safety rating from the Secretary which is unsatisfactory, such motor carrier shall have 45 days to take such action as may be necessary to improve such safety rating to conditional or satisfactory. After the last day of such 45-day period, if such motor carrier has not received a safety rating from the Secretary which is conditional or satisfactory, such motor carrier shall not operate a commercial motor vehicle . . .
(1) to provide transportation of hazardous materials for which placarding of motor vehicles is required in accordance with the regulations issued under this title . . .

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6. For years the Federal Highway Administration has had authority to issue an order directing any motor carrier forthwith to cease operations on the grounds that it is an "imminent hazard" (49 U.S.C. 521 [b][5]). The first exercise of that authority came this year.

7. P.L. 101-500, 104 Stat. 1213. The Motor Carrier Safety Act is to be codified as an addition to HMTA, 49 U.S.C.App. 1801, et seq.

(b) Review of Rating.—If a motor carrier who has received an unsatisfactory safety rating from the Secretary requests the Secretary to review the conditions and other factors which resulted in such motor carrier receiving the unsatisfactory safety rating, the Secretary shall conduct such review within 30 days after the date of such request.

(c) Prohibition on Federal Agency Use.—No Federal agency may use a motor carrier who has an unsatisfactory safety rating from the Secretary—

(1) to provide transportation of hazardous materials for which placarding of motor vehicles is required.

Observe that within the space of 10 days Congress passed two bills addressing the same perceived problem, i.e. the transportation of hazardous materials by motor carriers that are not in compliance with the Federal Motor Carrier Safety Regulations. The approach taken by the two bills was quite different. One, SFTA, took an after-the-fact approach, barring such transportation by carriers receiving a rating of unsatisfactory. Motor carriers are given a scant 45 days within which to improve the rating before being put out of business insofar as hazardous materials are concerned. SFTA applied to hauling any hazardous material in placardable quantities. HMTUSA took a different approach, establishing the permit system to regulate the hauling of hazardous materials from the outset. HMTUSA applied the permit system to specific groups of hazardous materials, but gave DOT authority to expand its application. It seems probable that this duplication of legislative effort was a result of confusion in the rush to adjourn and the preoccupation with the budget deficit. DOT is now faced with further duplication of effort, because it must by rulemaking implement both acts.

Given the shortcomings of DOT's safety rating system, as explained hereinafter, it would seem that the before-the-fact permit system is more likely to achieve positive results in promoting safety. On the other hand, the broader coverage of SFTA, applicable to any transportation of a hazardous material in placardable quantities, is an advantage offered by that bill.

Consider now the dimensions of the practical problem faced by DOT. FHWA's best estimate is that as of May 15, 1990 there were approximately 213,000 motor carriers subject to its safety jurisdiction. As previously observed, no one knows how many of those were hauling hazardous materials. As of that date, approximately 84,300 carriers had been audited and assigned ratings, leaving roughly 129,000 carriers still to be reviewed.[8]

A compliance audit, which is the first step in determination of a safety rating, takes about four hours of an inspector's time for a small carrier. Medium size carriers require about a day. Larger carriers may require a day and a half. At present FHWA is authorized for a work force of 450 inspectors, who must divide their time between compliance reviews and other motor carrier safety enforcement responsibilities. Despite the fact that FHWA has been issuing safety ratings for many years, less than half of the universe of carriers has been audited even once and assigned a rating. The

8. Truck Safety: Improvements Needed in FHWA's Motor Carrier Safety Program, p.4, GAO/RCED-91-30, Jan. 1991.

problem is compounded by the turnover in the industry. Carriers enter and leave the motor carrier industry with such rapidity that the duty of assigning safety ratings to all motor carriers is a Sisyphean task.[9] That was, however, the duty assigned to DOT by section 215 of the Motor Carrier Safety Act of 1984.[10] Associate Administrator Richard Landis was recently quoted in the press as calling the goal of having all carriers rated by 1992 "unrealistic," and the facts plainly bear out that assessment.

Further examination of safety review statistics contained in the GAO report cited above shows that, for those carriers rated in fiscal years 1987 through 1989, 33,864 were rated conditional, and 5,813 were judged unsatisfactory.[11] More than half of the carriers reviewed had significant defects that required correction in their safety programs. These carriers move into what FHWA terms its Selective Compliance and Enforcement cycle. Carriers are scheduled for repeat visits to determine whether indicated corrective action has been taken. A thorough compliance review of a carrier in this cycle may take three days or more, and may well lead to action for the imposition of civil penalties if compliance problems remain unabated.

Under FHWA's current policy, an unsatisfactory rating is supposed to trigger such a review and audit within six months in order to determine whether the carrier has taken action that would justify an improved rating. Due to manpower constraints, however, one year is a more likely time frame for the second review if nothing else occurs to change that process. Many are not revisited even within that time period.[12] Given those realities, the 45-day time frame envisioned in SFTA for improvement of an unsatisfactory rating is wholly unrealistic, but it is now the law.

DOT intends to interpret this 45-day disqualification in SFTA as applying only to those carriers who in the future receive an unsatisfactory rating rather than also applying to those carriers currently rated unsatisfactory. This interpretation is supported by the practical reality that DOT does not know how many of the 4,000-plus carriers currently rated unsatisfactory are hauling hazardous materials. Moreover it simply does not have the resources to reaudit and review within 45 days all of the carriers on this list.

There is another problem with the 45 days allowed for a carrier to improve its rating so as to remain in operation hauling hazardous materials. Thus far it has been FHWA's policy to keep the exact criteria for assigning ratings shrouded in mystery. I have learned, however, that one standard is that a carrier with an accident record worse than average may not be rated satisfactory. The only way for a carrier to solve that problem is to first correct whatever deficiencies may have existed in its safety program

9. In 1989, for example, about 21,200 carriers entered the business, while 16,500 exited. Fn. 8, supra.

10. 49 U.S.C. App. 2512.

11. A list of carriers with ratings of unsatisfactory, as of December, 1990, obtained by the author, contained somewhat more than 4,179, including some tank truck carriers and others who, by their names, are apparently engaged in hauling explosives or fireworks.

12. Fn. 8, supra.

and then to drive several million more miles to bring down the ratio of accidents to miles traveled.

A further problem involves keeping the ratings up-to-date. Some of the 75,000 ratings currently outstanding reflect the results of reviews conducted several years ago. A carrier may have a complete change of management, and its safety program may deteriorate significantly without triggering another review. Carriers receiving a satisfactory rating are not rescheduled for inspection unless something happens to alert FHWA to the existence of a problem. FHWA has a program called Commercial Accident Prevention Enforcement, which identifies carriers for a visit if they appear to have an inordinate number of accidents or out-of-service violations in random roadside inspections. However this system is not foolproof. For example, a 1986 licensing proceeding before the ICC involved a passenger carrier that was shown to be operating in complete disregard of safety regulations, although possessing a six-year-old satisfactory rating.[13]

Thus DOT is confronted with extremely daunting practical problems in its efforts to implement the mandate of SFTA and HMTUSA. If motor carriers are to be put out of business by issuance of an unsatisfactory safety rating, then the process must be accompanied by adequate guarantees of due process of law. Obviously the same principles also apply to the process of permit issuance. Therefore it is appropriate to examine the legal foundations for the safety rating process as it presently exists.

DOT's initial authority for the safety fitness rating program was derived from Section 304 of the Interstate Commerce Act, and it was therefore limited to common or contract carriers who required operating authority from the ICC. The Motor Carrier Safety Act of 1984 granted authority to bring within the program all operators of commercial motor vehicles, and required DOT to establish new procedures for the program by rulemaking.[14] The new regulations were finally adopted in late 1988 and they are now codified as 49 CFR Part 385.

There are three possible ratings that may be assigned: satisfactory, conditional and unsatisfactory. A fourth carrier designation, unrated carrier, applies to those not yet assigned a rating. The regulations define the meaning of the ratings as follows:

(1) Satisfactory safety rating means that a motor carrier has in place and functioning adequate safety management controls to meet the safety fitness standard described in Sec. 385.5 Safety management controls are adequate if they are appropriate for the size and type of operation of the particular motor carrier.

(2) Conditional safety rating means a motor carrier does not have adequate safety management controls in place to ensure compliance with the safety fitness standard that could result in the occurrences listed in Sec. 385.5 (a) through (k).

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13. J & J Bus Service, Inc., Extension, 1986-87 Fed. Car. Cases 37,265 (1986).

14. 49 U.S.C.App. 2512.

(3) Unsatisfactory safety rating means a motor carrier does not have adequate safety management controls in place to ensure compliance with the safety fitness standard which has resulted in occurrences listed in Sec. 385.5(a) through (k).[15]

Section 385.5, to which these definitions refer, is a listing of the entire gamut of violations, accidents or incidents which may occur related to the Federal Motor Carrier Safety Regulations and the Hazardous Materials Regulations. The distinction between conditional and unsatisfactory under these definitions may be difficult to apply; although an intermediate rating between satisfactory and unsatisfactory is undoubtedly needed in the practical application of the system. Any motor operation of substantial size is almost certain to have some violations or incidents which have occurred. If the investigator conducting a safety review has determined that adequate safety management controls are lacking, where is the line drawn between potential and actual violations in order to assign one rating or the other? The answer cannot be found in the regulations, and it is not intuitively obvious. The administration of the fitness rating program previously relied upon comparison with the records of carriers of similar size and with similar operations. That may well continue to be the case.

The regulations go further to list seven factors to be considered in determining a carrier's fitness rating, with adequacy of safety management controls at the top of the list, as it should be. The seven factors are as follows:

(a) Adequacy of safety management controls. The adequacy of controls may be questioned if their degree of formalization, automation, etc., is found to be substantially below the norm for similar carriers. Violations, accidents or incidents substantially above the norm for similar carriers will be strong evidence that management controls are either inadequate or not functioning properly.

(b) Frequency and severity of regulatory violations.

(c) Frequency and severity of driver/vehicle regulatory violations identified in roadside inspections.

(d) Number and frequency of out-of-service driver/vehicle violations.

(e) Increase or decrease in similar types of regulatory violations discovered during safety or compliance reviews.

(f) Frequency of accidents; hazardous materials incidents; reportable accident rate per million miles; reportable preventable accident rate per million miles; and other accident indicators; and whether these accident and incident indicators have improved or deteriorated over time.

(g) The number and severity of violations of state safety rules, regulations, standards and orders applicable to commercial motor vehicles and motor carrier safety that are compatible with Federal rules, regulations, standards and orders.[16]

15. 49 CFR 385.3.

16. 49 CFR 385.7.

These criteria pose some conceptual problems. There are no objective standards. Instead, there are references to the norms of similar carriers and national data, but there is no consideration of whether such averages are good, bad or indifferent. Neither is there any indication of where on this scale a carrier must fall in order to be considered satisfactory. It is possible, of course, that the average of a group of similar carriers may be very unsatisfactory in an objective sense. This lack of objectivity or fixed criteria in the standards means that the assignment of ratings may be highly arbitrary at any given time. To that extent, their value as objective indicators of conformance to the standards of operation as a safe carrier becomes questionable.

It is known that there is a computer algorithm by which these seven factors are weighed and a safety rating is assigned. However, that formula is not public knowledge, and, as demonstrated by the *Allen Line* case discussed below, FHWA has heretofore refused to voluntarily release the formula. FHWA's rationale is that if the formula were known, carriers would do only what is required to achieve a satisfactory rating. The reasoning seems specious. If carriers at least did that much, it would represent an achievement. As the rating statistics disclose, there is at present a large gap between the goal and the reality. Moreover, if carriers are to be put out of business, or have the issuance of permits dependent upon this process, then they have a right to know the exact standards by which they are to be judged.

The underlying problem is that the safety rating system was not designed by FHWA as a tool for determining who should be operating as a motor carrier, either in hazardous materials or otherwise. Instead, it was developed as an enforcement tool to identify those carriers who were in need of priority enforcement attention. It was admirably suited to that task. If the program is to serve as the foundation for a new emphasis on hazardous materials transportation by motor carrier, as envisioned by Congress, then it must be substantially improved and modified.

Thus far, only one decision has directly reviewed the legality of FHWA action in assigning an "unsatisfactory" rating to a carrier, and in that unpublished opinion FHWA's action was upheld.[17] The decision questions whether there is any property interest in a safety rating so that constitutional protections would apply. Even assuming that, however, the Court ruled that FHWA's current procedures satisfy the minimum requirements of due process of law.

The facts of the case revealed that the carrier failed to avail itself of the avenues of appeal that were available, and those facts illustrate what typically happens under the current system. A compliance review was performed in July, 1989, and a number of deficiencies were brought immediately to the carrier's attention. Based upon those deficiencies, FHWA issued notices of proposed civil penalties on 29 violations. The violations apparently involved driver qualifications, vehicle inspections and lack of required driver logs. The carrier did not request a hearing on the violations, but instead settled the civil penalties by paying a "substantial amount" of the penalties proposed. Shortly thereafter, the carrier requested a reinspection, indicating that its documentation was then in order.

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17. The Arrow Line v. Skinner, unpub. slip op., D.D.C., No. 90-0020, July 11, 1990.

Soon thereafter the carrier received a letter advising that an unsatisfactory rating had been assigned. The letter gave the name and contact information of an official who could be consulted for further assistance, but the carrier did not follow up on that invitation. Neither did it seek administrative appeal of the safety rating directly, as permitted by 49 CFR 385.7. Instead it filed a request for information under the Freedom of Information Act. That request lead to the release of some information, and apparently the carrier did not further challenge the exemptions under which FHWA claimed to withhold other information, including the critical algorithm used to assign safety ratings.

Subsequently, based upon a second compliance review performed the following month, the carrier's rating was upgraded from unsatisfactory to conditional. Having failed to gain a rating of satisfactory, the carrier filed suit challenging the legality of FHWA's procedures leading to issuance of the "unsatisfactory" rating. It claimed that the rating had rendered it ineligible to participate in the transportation of military personnel under contract with MTMC, had caused higher insurance premiums, and had unfairly represented it to the general public.

Judge Gesell first ruled that the right to do business with the federal government is not ordinarily a property right which is protected under the Constitution. Beyond that, however, he ruled that due process was not violated, because the regulations provide an opportunity for a hearing after an unsatisfactory rating has been issued. The rule announced by the U.S. Supreme Court in Matthews v. Eldridge[18] supplied the three factors to be applied in analyzing due process claims in administrative law:

> First, the private interest that will be affected by the official action; second, the risk of an erroneous deprivation of such interest through the procedures used, and the probable value, if any, of additional or substitute procedural safeguards; and finally, the Government's interest, including the function involved and the fiscal and administrative burdens that the additional or substitute procedural requirement would entail.

Judge Gesell applied those factors to the record before him in the following fashion:

> Here ample post-rating hearing was provided by regulation. Arrow was never left in the dark. Rather, it was precisely informed of its serious inadequacies, paid civil fines for some of its worst violations and was offered the right to petition for removal of the rating and protection by court review. It makes no claim its licensed business could not otherwise continue. The government's interest in safety is compelling and outweighs the risk that a pre-termination hearing would erroneously deprive companies like Arrow of their deserved status. Thus Arrow's

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18. 424 U.S. 319, 335 (1976). For further explanation of the process of balancing these factors see Walters v. National Ass'n. of Radiation Survivors, 473 U.S. 305 (1985).

liberty interest is tenuous at best and the post-hearing opportunity . . . is all the process due.

The 1990 legislation requires a fresh look at this analysis. Now an unsatisfactory safety rating may result in denial of a permit by DOT. Under SFTA it may have the effect of putting a carrier out of business within 45 days, whether or not it has an an opportunity for final and meaningful review of that rating before the deadline. Also, under policy established by the ICC since the record was closed in *Arrow Line*, the carrier will be precluded automatically from obtaining additional operating authority. The question is whether these new legal consequences of an unsatisfactory safety rating require greater procedural protections.

These matters involve licensing—the right to carry on a trade or business. These are vital interests to those involved, although the Court in Matthews v. Eldridge indicated that greater weight might attach to the claims of those such as Social Security claimants who are dependent upon the money involved for their sustenance. The cases that have considered licensing issues subsequent to Matthews v. Eldridge have determined that either pre- or post-termination hearings will provide adequate due process—provided that the post-termination hearing can be held and the issues resolved in a timely fashion.[19] Thus the 45-day time frame for resolution of issues under the SFTA probably will pass constitutional muster, if DOT demonstrates the ability to resolve the issues satisfactorily within that time frame. For the reasons previously noted, it faces a truly formidable task in meeting that goal.

With respect to the licensing process under HMTUSA, a positive determination of fitness in advance by DOT will obviously be required. Presumably this process will require an application by the carrier and an opportunity for a hearing. Fairness and due process could be ensured by an opportunity for a de novo review of the applicant's safety fitness rating as well as its overall conformity to the motor carrier and hazardous materials regulations.

In both circumstances however, there should be greater openness in the fitness rating process. As previously noted, the exact formula by which a safety rating is assigned is secret. It was not established through formal notice and comment rulemaking. Under the new legislation, these ratings will affect the substantive rights of carriers.

PERMITS FOR HAZARDOUS MATERIALS VS. PERMITS FOR HAZARDOUS WASTE

Congress created another paradox when it established the plan for permits for transportation of hazardous materials. In the future a carrier may be authorized to

19. Delahoussaye v. Seale, 605 F.Supp. 1525 (W.D. La. 1985); Hubel v. West Virginia Racing Comm., 513 F.2d 240 (4th Cir. 1975); Barchi v. Sarafan, 436 F.Supp. 775 (S.D. N.Y. 1977); Fink v. Supreme Court of Pennsylvania, 651 F.Supp. 1238 (M.D. Pa. 1987).

transport a hazardous material, but once that material becomes used, spent or spilled, it must then be given to a carrier with a different permit—one for hazardous waste. The permit program for hazardous waste is administered by the Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act (RCRA). EPA, however, lacks expertise in the necessary elements of safe transportation and is therefore not in the best position to determine a carrier's fitness. Indeed EPA is not concerned with the safety per se in the carrier's operation. The process under EPA's regulations simply involves submitting an application for a registration number.[20]

Furthermore, the trend in regulation of hazardous wastes is exactly opposite to that favored by HMTUSA with its strong emphasis upon preemption of state regulation in order to achieve national uniformity while maximizing safety. The culture under the environmental statutes views environmental concerns as primarily local in nature. As a consequence the emphasis is upon decentralization of regulatory control, with EPA establishing minimum standards for its approval of state or area plans. States are encouraged by the Resource Conservation and Recovery Act to develop their own hazardous waste programs. Such programs must meet minimum federal standards, but each state is otherwise free to apply regulations more stringent than the minimum standards of the federal EPA.[21] Some states have taken the liberty provided by the statute to implement their own permitting programs for transporters of hazardous waste. Certain of these programs are requiring hearings and evidence of fitness or public need before issuing such permits. Consequently any carrier considering the commencement of operations involving the transportation of hazardous wastes in any state with an approved state program must check the applicable state regulations closely.

EPA and DOT coordinated their regulations in 1978 so that EPA designated hazardous wastes were incorporated into the DOT definition of hazardous materials as Other Regulated Materials, category E (ORM-E). Now that DOT will be commencing the registration and permitting of motor carriers transporting hazardous materials, similar efforts should be undertaken. It makes no apparent sense to have two different agencies of the federal government engaging in essentially the same activity.

INCREASED ENFORCEMENT AND PENALTIES

The new act also seeks to enhance compliance and safety by strengthening enforcement and defining new offenses. Whether these statutory changes will accomplish the goal must be a matter of conjecture, but some observations are now appropriate.

Two entirely new offenses are defined and added to section 105, 49 U.S.C. 1804(e) and (f). The first is unlawful representation, making it an offense (a) to mis-

20. 40 CFR Part 263.

21. 29 U.S.C. 6926.

represent that a package is safe, certified or in compliance with the hazardous materials regulations, or (b) to represent that a container or vehicle contains a hazardous material when it does not. The second new offense is tampering. It is unlawful to alter or deface any marking, label, placard or description or to tamper with any container or vehicle used for the transportation of hazardous materials.

Whether these new provisions address a genuine problem is uncertain. Certainly the failure to describe a hazardous material properly was already an offense that subjected an individual to civil penalties. It is difficult to understand what benefit an individual might gain from representing that a shipment was a hazardous material where such was not the case. Some insight into Congressional intent is provided by the Senate Report, which made the following comment about the new misrepresentation offense.

> This subsection is intended to address an increasingly frequent problem, reported to DOT by enforcement personnel, involving negligent or willful misdescription of a shipment as containing a different hazardous material than indicated, or as containing a hazardous material when it does not.
>
> Misinformation regarding the actual hazardous material contained in a shipment presents the possibility of inappropriate emergency response which could cause, rather than avert, disaster. Misinformation indicating that a hazardous material is present when it is not poses the potential for wasting limited resources and diverting personnel from true emergencies. Both situations are unacceptable and must be prohibited by law.[22]

Section 12 of HMTUSA raised the ante for hazardous materials violations by amending 49 U.S.C. 1809 so as to increase and strengthen the penalty provisions. The maximum civil penalty was raised from $10,000 to $25,000, and a minimum civil penalty of $250 was inserted where no floor previously existed. Since the $10,000 maximum was established in 1975, the action in raising the ceiling does little more than keep up with inflation. The floor probably was unnecessary, since as noted hereinafter, most civil penalties for hazmat violations exceed that amount by a substantial margin.

Civil penalties are authorized against any person who "knowingly" violated the act or regulations. In another change to this section, Congress inserted a definition of the term, as follows:

> (3) Acting Knowingly.—For purposes of this section, a person shall be considered to have acted knowingly if—
>
> (A) such person has actual knowledge of the facts giving rise to the violation, or

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22. Senate Report No. 101-449, Aug. 30, 1990, 1990 U.S. Code Cong. & Adm. News 4595, 4609.

(B) a reasonable person acting in the circumstances and exercising due care would have such knowledge.

This definition in effect permits the imposition of civil penalties for negligent violation of the act or implementing regulations. From the standpoint of promoting safe transportation of hazardous materials, this is deemed to be perfectly appropriate.

The change in definition has the effect of overturning a 1952 U.S. Supreme Court decision in a case where a carrier was charged with violating the regulation requiring vehicles carrying hazardous materials to avoid tunnels and congested locations. A truck carrying carbon bisulphide had exploded in the Holland Tunnel in New York City, causing numerous injuries. While the case involved a criminal statute, 18 U.S.C. 835, which has since been repealed, the statutory language and the regulatory setting were identical to Section 1809 prior to this amendment. The court ruled that in order to sustain a conviction the government had to prove that the trucker knew that there was a more practicable, safer route and yet deliberately took the more dangerous route, or that he willfully neglected to inquire into the availability of an alternative route.[23]

The tenth circuit later applied that standard in a case where a carrier was charged with leaving unattended a trailer containing Class A Explosives. There the court ruled that all that was required was proof that the drivers intentionally left the trailer unattended, not that they also intended to violate the regulations.[24] The HMTUSA definition of the term "knowingly" is entirely consistent with that result, since it emphasizes that one need only have knowledge or notice of the controlling facts.

However, the importance of this statutory change is most vividly illustrated by a recent decision by the Court of Appeals for the Seventh Circuit which emphasizes that what one knows and what one should know are not the same thing.[25] This case involved civil penalties of $18,000 that RSPA assessed against a small package carrier because boxes containing radioactive materials were loaded too close to the cabs of some trucks. The carrier's defense was that it did not "know" of the violations, because the people who loaded the trucks in question were independent contractors rather than its employees. Because DOT failed to deal with the issue as to the status of these personnel in its decision, the Court of Appeals had to assume that they were in fact independent contractors. This result probably represents a tactical trial error on the part of DOT, and in the future it may challenge more vigorously a claim that drivers or other personnel of a carrier are independent contractors.

Accepting the independent contractor theory here, RSPA imposed the civil penalties based upon a definition of "knowingly," which it adopted and codified in 49 CFR 107.299:

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23. Boyce Motor Lines v. United States, 342 U.S. 337 (1952).

24. Texas Oklahoma Express, Inc. v. United States, 429 F.2d 100 (10th Cir. 1970).

25. Contract Courier Services, Inc. v. Research and Special Programs Administration, 924 F.2d 112 (7th Cir. 1991).

> A person . . . commits an act with knowledge or knowingly when that person (1) has actual knowledge of the facts that give rise to the violation, or (2) should have known of the facts that give rise to the violation.

DOT adopted that definition in 1983, relying upon a 1971 Supreme Court decision which held that it was unnecessary to enforcement of a criminal statute to show that the defendant was aware of the regulation that was violated. As the seventh circuit observed, however, it is one thing to say that a person is charged with knowledge of the law and may not plead ignorance of the law as a defense. It is quite a different thing to say that one may be charged with knowledge of facts, on the basis of what he should have known. As the court bluntly put it, "Section 107.299 obliterates any distinction between knowledge and ignorance. Its application in this case produced strict liability." The court further observed that when Congress wishes to impose liability for failure to make reasonable inquiry about the facts, it knows how to do so. In the Hazardous Materials Transportation Act of 1975 it did not take that step, but in the HMTUSA it clearly imposed the higher standard of duty. The change should make a significant difference in many future enforcement cases.

The amendment of subsection 1809(b) pertaining to criminal penalties is also interesting. The new tampering offense, discussed above, is subject to criminal penalties if a person "knowingly" tampers. Any other violation of the act or regulations is subject to criminal penalties only for a willful violation. The choice of the term "willfully" in the subsection imposing criminal penalties was deliberate. In commenting upon this difference one court stated, "Therefore in applying the standard of intent under section 1809(b), it may be necessary to show a voluntary, intentional violation of a known legal duty."[26]

At the same time Congress greatly increased the amount of potential criminal penalties. Originally section 1809(b) authorized a criminal fine of up to $25,000 or imprisonment for a term not to exceed five years. The act was amended to permit criminal penalties in accordance with Title 18, which currently subjects individuals to fines up to $250,000 and corporations up to $500,000, plus imprisonment for up to five years.

It is one thing to review what the act provides with respect to civil penalties, but it is more enlightening to see what is actually happening in terms of field enforcement. DOT issues an annual review of its civil penalty assessment activity which is quite revealing. DOT's most recent annual review of civil penalty actions involving hazardous materials transportation, covering the period through FY 1989, revealed that total collections were up sharply in FY 1989 after being down in 1988. Total penalties assessed in FY 89 amounted to $1,732,696, compared to $1,192,975 in FY 88—an increase of 45%. The FY 89 total is significantly more than in any of the five years covered by the study. Comparative totals are displayed in table 1.

Each of the modal administrations within DOT handles the process of assessing civil penalties for hazardous materials violations moving via that mode, while RSPA assesses penalties involving intermodal shipments or involving packaging, cylinder or

26. United States v. Allied Chemical Corp., 431 F.Supp. 361 (W.D.N.Y. 1977).

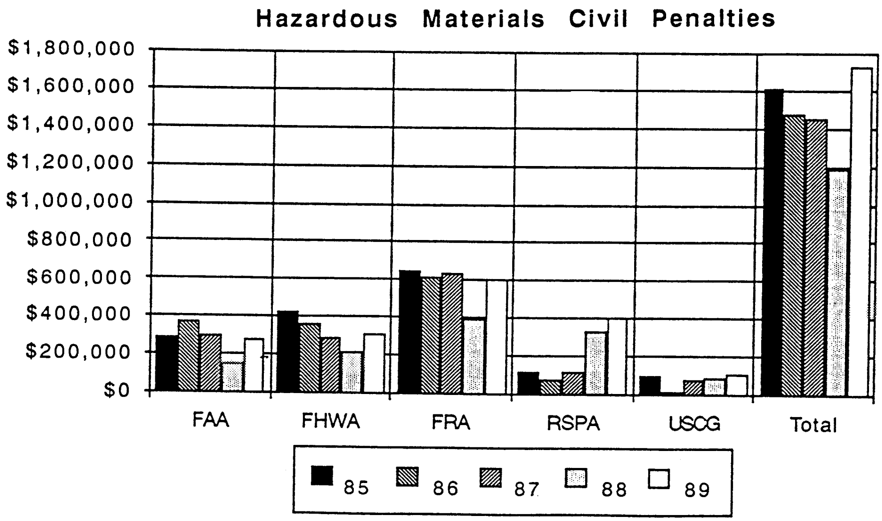

Table 1 - Hazardous Materials Civil Penalties

tank car suppliers and testers. A review of the details of reported penalty actions continues to reveal significant differences in the approach to the enforcement process among the modal administrations.

FHWA reported a total of 87 cases producing total penalties of $310,836, for an average of $3,573 per case. The great majority of those cases involved multiple counts—an observation that holds true among all of the modal administrations. Consequently it is impossible to calculate an average per count. Many of the penalties assessed by FHWA did not involve hazardous materials violations per se, but instead involved such offenses as driver's log violations which happened to occur on movements of a hazardous material. One factor that stands out is that over half of the cases involved companies designated as both shipper and carrier. This seems to indicate that there may be a certain laxity in such details as properly preparing shipping papers when a company is hauling is own goods.

RSPA processed 118 cases producing $408,600 in civil penalties for an average of $3,462 per case. The largest single case involved a fine of $30,000. The shipper offered a flammable liquid (an inhalation hazard) for transportation in unauthorized intermodal portable tanks, failed to mark the tanks with the proper shipping name, and failed to properly prepare the shipping papers. In this instance it seems that RSPA applied the authorized maximum of $10,000 for each count. It is noteworthy that substantial civil penalties were collected from some foreign shippers. In addition importers were penalized for failure to inform their foreign shippers of the hazardous materials regulations that would apply to the shipment in this country, such as description and packaging requirements.

In the past there has been some criticism of shortcomings in the reporting of hazardous materials incidents. Perhaps as a reflection of that criticism, RSPA imposed civil penalties against many companies for failure to submit the hazardous materials incident report form (DOT 5800.1) following an accidental release of materials. Penalties for this noncompliance ranged from $1,000 to $1,500. The clear lesson to be learned is to pay attention to reporting requirements and send in the 5800.1 forms.

Unlike previous years, the report for FRA did not reveal the nature of the offenses for which penalties were assessed. The report simply lists the companies involved in each case and the amounts assessed. FRA processed 87 cases with a total value of $611,810, for an average of $7,198. However 21% of the total, $130,600 was accounted for by four cases involving the Burlington Northern Railroad. Another $99,550 was assessed against Southern Pacific Transportation Company in five cases. These totals are meaningless, however, due to the practice of the large railroads in handling civil penalty matters. These railroads will wait until a substantial number of notices have accumulated and then have a consolidated negotiating session with FRA. The remaining penalties were scattered among a large number of companies, including shippers as well as railroads.

The majority of penalties assessed by FAA were against shippers. FAA processed 28 cases and collected $282,850, an average of more than $10,000 per case. The largest penalty, $40,000 was assessed against Chevron, U.S.A., Inc. for offering a shipment of resin solution, methyl ethyl ketone, and acetone in a leaking package. The shipment was not properly marked or labeled, and the shipping papers did not properly identify the shipment.

As in past years the penalties assessed by the Coast Guard are significantly lower than those of the other administrations. The Coast Guard collected $118,600 in 92 actions, for an average of $1,289.

In passing it should be noted that section 16 of HMTUSA also undertook to strengthen enforcement of the act by authorizing the employment of an additional 30 inspectors, 10 of whom are to be specifically assigned to radioactive materials transportation. In a classic example of micro-management by Congress, the act directed that at least one of the 10 would be assigned to RSPA, three to FRA and three to FHWA. The remaining three radioactive materials inspectors could be assigned at the secretary's discretion.

As noted above, there appears to be a considerable disparity among the modal administrations of DOT with respect to their approach to enforcement of the hazardous materials regulations. But the disparity in approaches to enforcement among the various states is even greater.[27]

A study recently prepared for the National Governors' Association (NGA) documented this disparity in the degree of enforcement and the severity of penalties for hazardous materials shipment violations from state to state (see table 2). However

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27. Section 22 of HMTUSA provides for establishment of a working group to address the need for uniformity among the states in hazmat permitting forms and procedures, but it says nothing about enforcement.

there has been substantial progress in at least developing uniform regulations. Forty-nine states had adopted the federal HMR in whole or in part, and New Mexico was expected to follow suit shortly. Of the 49 states, 20 have adopted all sections of the HMR while 27 have adopted compatible state rules. Forty-eight carry out roadside inspection and enforcement of hazardous materials regulations. Forty-three of those states grant their inspectors the power to search the contents of vehicles without a search warrant. Thirty-four states also inspect carrier facilities for compliance, and 22 conduct inspections at shipper facilities.

Nevertheless there is a wide disparity among the states concerning the severity of fines or other penalties that may be imposed for violations of hazmat regulations. The table at the end of this article summarizes the enforcement penalty authority in each of the states as reported by the NGA study. Not only does the penalty authority differ sharply among the states, but in most instances it is also considerably less than the penalty authority at the federal level.

One further anomaly that deserves recognition at this point is that the railroads have succeeded in winning complete federal preemption of state hazardous materials regulation by utilizing the Federal Railroad Safety Act rather than the Hazardous Materials Transportation Act. Recently the U.S. Supreme Court refused to review a decision issued last year by the Sixth Circuit, which held that the Federal Railroad Safety Act (FRSA) precludes states from regulating hazardous materials shipments by rail within their borders.[28] That decision upheld an earlier district court decision that the Ohio PUC's regulations governing hazmat shipments via rail were preempted by FRSA, even though the Ohio regulations were virtually identical to the federal regulations. The decision did not rest upon any inconsistency between state and federal regulation of hazardous materials or upon any theory of burden upon interstate commerce. Instead it held that by the FRSA Congress intended to completely preempt the field of railroad safety regulation, leaving no room for state intervention. Interestingly, the Hazardous Materials Transportation Act of 1975 provided for states to cooperate in enforcement of hazardous materials regulations, but under this decision such enforcement efforts must be limited to enforcement of the federal law and regulations. Unfortunately there are practical barriers to effective enforcement of federal regulations by state authorities.

In an amicus curiae brief, nine states had supported Ohio in seeking Supreme Court review of the CSX decision. That brief made this pertinent observation:

> In just six years, the amount of hazardous materials transported has increased 100%. By 1990, 4 billion tons of hazardous materials were being transported annually, with as many as 500,000 movements a day. Unfortunately, in the face of these sobering statistics, the performance of the federal rail hazardous materials program can only be described as deplorable.

It also appears that the railroads were able to obtain reinforcement of the CSX

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28. CSX Transportation, Inc. v. Public Utilities Comm. of Ohio, 901 F.2d 497 (6th Cir. 1990). Cert. denied, 111 SC 781.

Table 2. State Penalties for Hazardous Materials Shipment Violations
Source: National Governor's Association, 1988

State	Category	Penalty
Alabama	Class 1 Misdemeanor	$1-$2,000 and /or max. 1 year in jail
Alaska	Not enforcing violations at this time	
Arizona	Criminal Civil	$0-$1,000 $1,000-$5,000
Arkansas	Municipal courts determine penalties	
California	Misdemeanor	$2,000
Colorado	Criminal Civil	$25-$1,000 and/or max. 1 year in county jail $25-$250
Connecticut	Criminal	1st offense - $1,000/6 mo. in prison 2nd offense - $2,000 Resulting in death - $10,000 or 10 years in jail or both
Delaware	Criminal Civil	$25-$5,000 $500-$5,000
Florida	Criminal Civil	$1,000 and/or 1 year in jail $50-$250
Georgia	Criminal	$250-$1,000
Hawaii	Civil	$0-$2,000 per violation
Idaho	Misdemeanor Civil	$0-$1,000 or up to 1 year in jail $0-2,000 per violation
Illinois	Criminal Civil	$0-$25,000 per violation $0-$10,000 per violation
Indiana	There are 92 counties with over 100 court systems, each of which sets its own fine system	
Iowa	Criminal	$0-$135 per violation
Kansas	Left to discretion of judge	
Kentucky	Criminal	$200-$25,000
Louisiana	Criminal Civil	$0-$25,000 $0-$25,000
Maine	Criminal	Class D Crime
Maryland	Criminal	$0-$1,000
Massachusetts	Criminal Civil	$0-$500 $0-$100
Michigan	Criminal Civil	$100 and/or 90 days in jail $200
Minnesota	Misdemeanor	$700
Mississippi	Civil	$0-$500
Missouri	No published list—however, there are 14 counties where penalties are classified as misdemeanors and range from $5-$500	

Table 2, continued

State	Category	Penalty
Montana	Civil	$50-$250
Nebraska	Class III Misdemeanor	$25-$50
New Hampshire	Criminal Civil Administrative	$55-$50,000 $250-$25,000 Loss of carrier permit
New Jersey	Civil	1st offense - $50-$5,000 2nd offense - $100-$10,000 3rd offense - $250-$25,000
New Mexico	Legislation being introduced to get authority to adopt federal regulations—no penalties attached	
New York	Civil	1st offense - $250-$1,000 2nd offense - $1,000-$2,500 or imprisonment for 90 days
Nevada	Criminal Administrative	$0-$1,000 $0-$500 per day
North Carolina	No criminal penalties	
North Dakota	Criminal	1st offense - Infraction 2nd offense - Class B misdemeanor
Ohio	Criminal	$25-$1,000 levied by local courts
Oklahoma	Civil	$0-$1,000
Oregon	Criminal Civil Administrative	$1,000 or 3 months in jail $10,000 Suspension of operating authority
Pennsylvania	Criminal	$50-$50,000
Rhode Island	1st offense Each subsequent offense Resulting in death or injury	$100-$500 or 1 year imprisonment $200-$1,000 or 1 year imprisonment $10,000 and 10 years imprisonment
South Carolina	Criminal	$45-$110 per violation
South Dakota	Criminal	$100-$1,000
Tennessee	Criminal	$0-$500 per violation
Texas	Criminal	$100-$200
Utah	No published penalties	
Vermont	Criminal	$250-$2,500
Virginia	Criminal Civil	Class 1 misdemeanor—up to 1 year in jail and/or max. of $1,000 per violation $0-$10,000
Washington	Criminal	$47-$500 depending on the court
West Virginia	Civil Administrative	Varies Varies
Wisconsin	Civil	$10-$200 per violation
Wyoming	Criminal Administrative	$0-$750 and/or 6 months in jail Suspend or cancel operating authority

decision when Congress passed HMTUSA. With little fanfare or attention, that act included section 30, which provides:

> Nothing in this Act, including the amendments made by this Act, shall be construed to alter, amend, modify, or otherwise affect the scope of section 205 of the Federal Railroad Safety Act of 1970.

The net result of this court and legislative activity is that railroads have won complete federal preemption of hazardous materials transportation via that mode. State regulations over all other modes—highway, water and air—are subject to the new and detailed inconsistency standards of Section 4 of HMTUSA, which amended 49 U.S.C. Sec. 1804.

THE ROLE OF HAZARDOUS MATERIALS COMPLIANCE AND ENFORCEMENT

In the broad picture, compliance and enforcement efforts by DOT and responsible state agencies are commendable. They need to be continued and reinforced as Congress intended. Such efforts will be particularly valuable in educating less established carriers and shippers in the need for a strong safety program in hazmat transportation.

Nevertheless, civil penalties and even occasional criminal sanctions are not the primary deterrent to unsafe practices in the transportation of hazardous materials. The potential monetary loss from civil tort liability for hazardous materials incidents, serious personal injuries and even death far exceed the amount of civil penalties. As noted previously, in FY 1989 DOT penalties involving hazardous materials violations totaled somewhat in excess of $1,700,000. Contrast that with a single $18 million dollar wrongful death judgment awarded against a railroad in Florida in 1980, involving both compensatory and punitive damages, for improper track maintenance that caused a derailment and subsequent release of anhydrous ammonia. Or consider the $16.25 million in punitive damages assessed against Monsanto by an Illinois jury for a 1979 spill of dioxin-contaminated chemicals from a tank car. That award came at the conclusion of a three-and-one-half-year trial, the longest jury trial in American history up to that time. That kind of liability exposure has the ability to wonderfully focus the minds of corporate management.

In addition, every hazmat spill is subject to the liability provisions of the Resource Conservation and Recovery Act. Under RCRA, carriers and shippers are jointly and severally liable for response costs incurred to clean up the spill and to avoid collateral damage. This liability is strict and absolute, so that negligence or due care is an irrelevant consideration.

In addition to such civil damages, shippers and carriers must consider the liability for lost and damaged cargo, injuries and workmens' compensation expense, loss of productivity and loss of customer goodwill that accompany every transportation incident involving hazardous materials. These considerations are by far the greater incentive to safely managing the hazardous materials transportation process.

3

INTERNATIONAL STANDARDS AND DOCKET NO. HM-181

Lawrence W. Bierlein

INTRODUCTION

The U.S. Department of Transportation (DOT) regulates the transportation of a variety of products and wastes that could cause acute injury to humans if released from their packaging in an uncontrolled manner during transportation. Included in this category of hazardous materials are those that might destroy transportation equipment, such as aluminum-corrosive materials aboard aircraft, that ultimately could injure people operating the equipment and on the ground.

For approximately the past decade, DOT has controlled materials in transportation that have been identified by the U.S. Environmental Protection Agency (EPA) as posing threats to the environment if spilled. These environmentally hazardous materials may not pose a direct threat to human health or safety. In addition, DOT has regulated some health hazards but on a limited scale, including radioactive materials and etiologic or human disease-producing agents.

The United States was the leader in hazardous materials regulation for many of the decades since the initial Interstate Commerce Commission's controls in the 1880s. U.S. transportation regulations were more encompassing, more detailed, and more dynamic than those maintained by other countries. Since the 1960s, however, other countries as well as regional groups of countries have developed their own expertise and rather different rules and approaches to regulation of hazardous materials.

We are now in the later phases of a trend under which national regulations, such as those implemented by DOT in the U.S., are being subordinated to international codes in the name of uniformity and facilitation of world commerce. Although laudable for a number of reasons, this move has negative features which, to date, have been addressed inadequately by government and industry.

The key U.S. institutional players shaping this trend include DOT as the "competent authority" that attends international transportation meetings and represents the nation's interests; and EPA and OSHA (the Occupational Safety and Health Administration), which represent U.S. environmental and occupational safety and health interests in similar international meetings on those subjects. Some of the international groups involved in hazmat transport regulation include the United Nations Committee of Experts on the Transport of Dangerous Goods, regional European road and rail authorities (RID/ADR), the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO), the International Air Transport

Association (IATA), the United Nations Environmental Programmes (UNEP), and the International Labor Organization (ILO).

KEY INSTITUTIONAL PLAYERS

U.S. Department of Transportation

For many years, DOT has sent delegates to and often has chaired important sessions of the United Nations (UN) and other international bodies on the subject of hazardous materials transportation regulation. This has been and continues to be done by a staff far too limited in size and resources to do the job effectively. It has often been uncertain whether the agency's budgetary concerns would permit travel of even a single participant. In addition, some individuals and foreign groups have challenged the authority of DOT to make international agreements. They have raised the question of whether DOT's statutory power to regulate safety in shipping hazardous materials in interstate and foreign commerce extended to the establishment of uniform international codes.

DOT's role in international matters was finally clarified in the Hazardous Materials Uniform Safety Act of 1990 (HMTUSA). The act declares that "the Secretary shall participate in international forums that establish or recommend mandatory standards and requirements for the transportation of hazardous materials in international commerce." HMTUSA further specified that domestic U.S. regulations

> shall be consistent with standards adopted by international bodies applicable to the transportation of hazardous materials. Nothing [in this law, however] shall require the Secretary to issue a standard identical to a standard adopted by an international body, if the Secretary determines the standard to be unnecessary or unsafe, nor shall the Secretary be prohibited from establishing safety requirements that are more stringent than those included in a standard adopted by an international body, if the Secretary determines that such requirements are necessary in the public interest.

Although the basic framework of a regulatory code is in place in the UN, frequent adjustments are necessary and, in addition, a number of major new programs and reworking of fundamental concepts are planned. This activity, therefore, is ongoing.

In addition to DOT, both EPA and OSHA have indirect involvements in transportation. They participate in the development of international conventions and standards in their respective subject areas. These subject areas bear on transportation. See the discussion below about the United Nations Environemntal Programmes (UNEP) and the International Labor Organization (ILO).

United Nations Committee of Experts

This group of 14 nations and a number of official government and industry observers meets periodically in subcommittees and, every two years, finalizes changes to the UN Committee Recommendations on the Transport of Dangerous Goods. Their published recommendations appear in a volume referred to as the *Orange Book* because of its color. The UN Committee endeavors to address all issues common to the different modes of transportation, i.e., that are not unique to a particular mode such as air commerce. These issues include fundamental provisions such as those defining and classifying hazards, establishing proper shipping descriptions for those materials, and addressing the applicable packaging, marking, labeling, documentation and placarding requirements for shipments.

The *Orange Book* contains a series of recommendations which, by themselves, are without force of law. They must be implemented by some other code or regulatory body in order to come into mandatory effect. Because of the diversity of nations involved and the intention of all participants that these recommendations be implemented in all nations, the recommendations are of critical importance. However, as noted below, their importance is often underestimated.

RID/ADR

This joining of road and rail regulatory authorities in western Europe has importance for U.S. industry. This importance derives from Europe's strong position in international commerce. The region includes several of our major trading partners. In addition, one must recognize that the majority of voting positions on the 14-member UN Committee of Experts are held by western Europeans. As a result, RID/ADR's influence is felt strongly outside the immediate jurisdiction of its membership.

The International Maritime Organization

There are two ways in which the IMO plays a critical role. First, its Dangerous Goods Code is applied as law in many maritime nations and ports around the world and is used by all vessel operators as the regulatory code of choice. This code is built upon the foundations of the UN recommendations. It also addresses all aspects of cargo loading, stowage and handling at sea in light of the unique properties of that mode of transportation in terms of duration of travel, sailing in rough weather, and exposure to both heat and moisture.

The second important facet of IMO's role is its Marine Environmental Protection Committee (MEPC). This committee is charged with implementing the various annexes of the primary international convention on marine pollution, called MARPOL 73/78. This convention compels restrictions on a wide range of materials that had not been subject to control in transit before, such as materials which might bioaccumulate in seafood, or which, when spilled, might negatively affect the aesthetics of seafood (e.g., so-called "black tainters") or beaches. Among other things, this convention directs the IMO to develop provisions governing the designation, identification, packaging, labeling and documentation of marine pollutants.

Much as the U.S. DOT adapted its hazardous materials transportation regulations to accommodate EPA-designated hazardous substances and hazardous wastes, the IMO has carried out this responsibility by adapting its historic dangerous goods code to include new provisions on marine pollutants.

The International Civil Aviation Organization and the International Air Transport Association

ICAO is UN-affiliated, but IATA is not. ICAO is largely made up of national governments, but air carriers and airline pilots have a vote in ICAO. ICAO, based in Montreal, performs for the air mode much the same functions as IMO does for the maritime mode. ICAO published its "Technical Instructions on the Transport of Dangerous Goods by Air," based upon the fundamental decisions developed by the UN Committee of Experts.

IATA is a commercial air carrier body which reprints, with some carrier-developed additions and deletions, the ICAO "Technical Instructions." Because they are applied commercially, the IATA regulations are the most common code found in air transportation, even though they have not been enacted by governments.

The United Nations Environmental Programmes

UNEP touches on many aspects of environmental protection. Under a number of codes recommended by the UN, UNEP attempts to identify, classify, document and label transboundary movements of hazardous wastes. These include a wide but ill-defined range of wastes not covered by the UN recommendations on dangerous goods transportation.

The International Labor Organization

The ILO is in the process of developing a standard similar but not identical to the U.S. OSHA hazard communication standard. As with OSHA, the key to this international system would be a paper, akin to a Material Safety Data Sheet (MSDS), identifying the various hazards and precautions to be taken with the material in production, storage, transportation and use. Container labeling is also likely under the ILO system, in order to be able to correlate the document with the container holding the material it describes. Here, again, another code is developing involving documentation and information that must appear on the exterior of hazardous materials packaging.

COORDINATION OF INTERNATIONAL STANDARDS

When OSHA, DOT, EPA and others develop regulations that affect the same materials, a mechanism exists—at least in theory—through the White House and the Office of Management and Budget, to coordinate these efforts and to avoid redundancies. In the international arena, however, no clear bridge exists between disparate UN organizations. Individual entities appear to prefer to avoid the coordination of responsibility. Instead, they choose to march to their own cadence based on their perception of needs. The UN Committee of Experts on the Transport of Dangerous Goods has had the opportunity to receive briefings from these various groups, and has expressed its view forcefully that transportation concerns should be addressed by them with no confusing duplications of requirements by other organizations. To date these pleas have met with only minimal acknowledgment.

A facet of this lack of coordination and communication, apparently encountered in all participating countries, is that delegates from the environmental and occupational safety agencies do not interact well, if at all, with delegates from transportation agencies. A delegate from one country on the Committee of Experts may therefore be in the awkward position of complaining about an environmental or labor proposal introduced by an expert in another agency from the same country.

Safety Impact of Lack of Coordination

The two key elements of all hazardous materials transportation codes are effective packaging and clear hazard communication. Because of the vast array of materials regulated and the wide variety of hazards they pose, all approaches to regulation share a similar complexity. Because the result of failure to meet the safety requirements often is an accident, or worsening of a situation due to confusion, clarity in understanding on the part of the affected industry is essential.

In the hazardous materials handling field, confusion equals danger. The proliferation of requirements applicable to the same materials and similar hazards by multiple agencies fosters confusion. Such confusion exists despite the acknowledged goal of each body to achieve and maintain safety.

The UN Committee of Experts and the IMO/ICAO codes have recognized roles and are in a mature state. There are many other international programs in their formative stages. Some require national ratification before coming into effect. Nonetheless, we may anticipate further problems with multifaceted international hazardous materials packaging and communications requirements, which will increase the effort and costs involved in achieving compliance and will affect safety negatively.

Domestic Impact of International Regulations

The new DOT legislation, the General Agreement on Tariffs and Trade (GATT), and other trade factors require adaptation of U.S. regulations so that they are the same as or at least compatible with international standards. A classic example of the fruits of this process of adaptation is DOT's Docket No. HM-181, published as a final rule on December 21, 1990. This massive new regulation adopts, for domestic use, the UN approach to regulation as a substitute for the two volumes of the Code of Federal Regulations (CFR) that have applied in the U.S. over the past eight decades. Changes include the UN definitions and test methods to identify hazard classes, international shipping descriptions, and a very different approach to packaging called "performance-oriented standards."

One concern with this approach is substantive, because of the view of many that the UN packaging standards result in lower quality packaging than has been in use in the U.S. to date. Generally this result flows from two basic differences in approach between the UN standards and the historic DOT packaging specifications. First, the European attitude, which dominates the UN, favors a more relaxed approach to regulation, often relying upon a sense of fair play and honor, unlike the U.S. rules which are written with the lowest common denominator in mind. Second, the UN approach subjects all packaging to the same level of testing and, therefore, quality. The flaw in this approach is that steel drums are not the same as steel pails or paper bags. If flimsier packaging were held to the traditional test levels for 55-gallon steel drums, all would fail. Therefore, the UN standards were adjusted downward to accommodate such packaging with the result that quality of larger packaging for liquids is lower than we are used to in the United States.

A more subtle concern in this movement toward international harmony is with U.S. implementation of standards written somewhere else. This concern has several subparts:

1. On an international committee, the U.S. has but a single vote. Domestic implementation of such an international committee's standards represents a significant loss of control.

2. Such committees often may be geographically imbalanced. Today's UN Committee of Experts, for example, has a majority of delegates from the rapidly consolidating European community which, in my view, ought to get one vote rather than eight.

3. Participation procedures are almost nonexistent. The international committees are small clubs, and one must know the rules to be effective. Late-filed papers and papers drafted *at* the meeting often are adopted, with no input from anyone other than those present. Attendance at the meetings is imperative if one is to protect one's interests, but only official observers are allowed to attend. Fortunately, I have assisted two international groups to obtain this recognized status, and I expect more will follow, but for the moment the opportunity to participate is very limited.

4. The process of achieving international reconciliation of regulations is inordinately slow. It takes at least two years at the UN level and varying

periods of time at the IMO, ICAO and national regulatory levels. The system also lacks a mechanism for quick action to accommodate unforeseen situations, or to develop and publish internationally acceptable interpretations of the standards.

5. In the United States, the notice-and-comment rulemaking process takes place under the Administrative Procedures Act. The process becomes far less meaningful when initial decisions are made in Geneva or some other international center. When the idea comes to the U.S., the burden is on opponents to overturn it, or it will become law applicable to domestic transportation.

RECOMMENDATIONS

The only way for the United States to achieve effective and safe reconciliation of its regulations with those of its major trading partners is to accord the task the importance it deserves. The United States, as well as other nations, must devote more time and attention to the problem and the process.

If a nation's citizens have plants in other countries it should consider the impact of the trend toward international regulation of hazardous materials transportation. It should also seek the support of the countries in which the plants are found in international negotiations concerning such regulation.

Because of DOT's participation in the international meetings—even though it has been at far too low a level of effort considering the importance of the issues—we in the U.S. are better off than those in all other non-European nations. But improvements are needed.

My suggestions involve changes in companies, in associations, and in government. For companies, the only way to assess the effect of proposed changes is to attempt to work through in a detailed way their impact on products, packaging, and modes of transportation used to ship to important destinations. The exercise is difficult and time consuming. Once a company identifies a point of concern, it must determine the best mechanism for voicing that concern. The procedural status of the regulation that causes the concern must be taken into account.

Some companies rely on associations to study and be aware of international developments in regulation. Such reliance can be dangerous because few associations devote much time to such study. Involvement in the UN is open to associations, but they must seek observer status, which is granted reluctantly, and they must be multinational in their membership and perspective. I recommend that such associations involve cooperation between nations from all continents—not just the United States and nations in Europe. An association that wants to be involved must dedicate the time necessary to learn about international regulatory processes, to analyze the changes that are taking place, and to gather and express the views of the industry it represents.

The U.S. government needs to direct more resources to international regulation. More people need to follow international regulatory developments than domestic programs. The people who carry out international standards coordination need to be able to devote the time and must have the resources to participate effectively. Such involvement requires travel funds to attend scheduled meetings and pre-meetings such as those the European delegations hold to prepare for key scheduled meetings. U.S. participants must also have the time and resources to lobby other delegations for worthwhile changes that might not be achieved without this effort.

All concerned parties—companies, associations and governments—must work toward improvements in the process such as minimizing geographical imbalance, avoiding voting blocs, speeding deliberations, and clarifying the methods by which the facts essential to sound decisions are brought before the international bodies.

Because of the importance of hazardous materials transportation restrictions on trade, greater involvement of those interested in facilitating trade and conducting diplomacy are required. The United States often loses on key points because we have been looking at the trees and missing the forest. The implications of delegating the authority to regulate domestic affairs to overseas competitive nations should have been and continues to need to be explored thoroughly. To my mind, this has not been done, because the attention devoted to the subject by all parties has been too narrow, and too focused on specific papers dealing with specific commodities. The *concept* of international regulation needs reassessment and refinement before we get too much further into it.

This reassessment ought to include the subject of multiple international bodies applying critically different rules to the same materials in transit. This reassessment should include the development of a recognized mechanism for (1) coordinating the input made to international bodies by our domestic government agencies (and assuring that the views they are expressing truly represent the best interests of the country), and (2) coordinating through a single office of the UN the various international standards that are developed, with authority granted to such an office to resolve disputes and to make determinations on the relative benefits of competing concepts that may be developed in parochial regulatory committees.

It is crucial that we recognize that international regulatory trends will have serious impacts on U.S. domestic as well as foreign trade.

4

INTERAGENCY CONFLICTS IN THE REGULATION OF HAZARDOUS MATERIALS IN TRANSPORT: THE NUCLEAR MATERIALS EXAMPLE

Melinda Kassen

During consideration of reauthorization for the Hazardous Materials Transportation Act (HMTA), several interests asked Congress to fashion legislation that would establish clearer roles for federal, state, local and tribal agencies, a concept the Environmental Defense Fund (EDF), one of these entities, dubbed "enhanced federalism." Concerns regarding the lack of effective interagency coordination drove much of the testimony involved in the reauthorization hearings. There were particular concerns about the transport of nuclear materials. Here regulatory authority is parceled out between the Department of Transportation (DOT), with relatively little expertise regarding nuclear materials; the Nuclear Regulatory Commission (NRC); and the Department of Energy (DOE). The DOE has two roles. It is both a major shipper of nuclear materials and a federal agency that is allowed to certify its own compliance with NRC regulations to DOT.

Clearly the kind of jurisdictional friction that exists in the transport of nuclear materials can occur in the transport of nonnuclear hazardous materials. The following provisions, all of which encompass regulation of hazardous materials transporters, are the potential sources of such friction:

1. The cradle-to-grave regulatory requirements for hazardous materials mandated by the Resource Conservation and Recovery Act[1] and enforced by the states and the Environmental Protection Agency (EPA).

2. The community right-to-know provisions of Title III of the Superfund Amendments and Reauthorization Act (SARA).[2]

3. The worker protection and right-to-know provisions of the Occupational Safety and Helath Act,[3] administered by the Department of Labor.

Furthermore, the lack of agency coordination with regard to all aspects of the in-

1. 42 U.S.C. section 6901, et seq. (1990).

2. 42 U.S.C. section 9601 (1990).

3. 29 U.S.C. section 653, et seq. (1990).

ternational transport of hazardous materials is apparent to all practitioners in this field. Different versions of enhanced federalism were advocated in the hearings by individuals who represented different groups. They did so to provide structure to the relationship between enforcement agencies, but also to describe more clearly their tasks. For example, EDF advocated that Congress direct the federal agencies to focus their resources on:

1. A comprehensive inspection program of carrier terminal and materials/waste storage facilities

2. The creation of a comprehensive regulation for carriers

3. Ensuring the safe design, manufacture and ongoing use of containers carrying nuclear materials

4. Long-term planning for the massive, inevitable shipment of nuclear waste

With regard to the federal areas of responsibility delineated above, EDF suggested that Congress would need to take formal action to direct the appropriate agencies to accomplish these tasks.[4]

This paper first describes the overlapping authorities of the agencies responsible for nuclear waste. Then, it reviews some of the events under the previous regime for regulating nuclear materials transport. Next, it compares the reforms that EDF and others, notably Congress' Office of Technology Assessment (OTA), advocated with the changes actually enacted in the Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA). Finally, it concludes with some thoughts about continuing gaps in the legislative framework and proposes new areas for cooperation between the participating agencies.

REGULATORY FRAMEWORK

DOT has the primary responsibility for regulating the shipment of nuclear materials.[5] Under HMTA, DOT issued a series of regulations governing packaging, placarding, vehicle standards, training for some personnel categories, routing and shipping papers.[6] However, with regard to the shipment of nuclear materials, DOT has shared its authority with, or has ceded large parts of its authority to, the NRC and DOE. This

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4. EDF also suggested that under an enhanced federalism system, state, local and tribal governments concentrate on: (1) performing inspections and enforcing safety regulations for shipments in transit and (2) establishing surface routes through their jurisdictions.

5. 49 U.S.C. section 1801, et seq. (1990).

6. 49 CFR parts 171-179.

has occurred because DOT has little expertise in the field of nuclear safety and because of the independent legal authorities and responsibilities of those agencies.

Thus, DOT has entered into a Memorandum of Understanding with the NRC to allocate responsibility for the regulation of containers.[7] The Atomic Energy Act delegates to NRC the authority to regulate packaging and other aspects of transportation of shipments of high-level radioactive materials made by NRC-licensees (e.g., owners and operators of commercial nuclear power plants).[8] NRC also must approve routes for shipments of radioactive materials that need physical protection, and has promulgated safeguards and security regulations to prevent theft or sabotage of such materials in transit.[9] However, while NRC approves such routes, shippers must still submit routes that are compatible with DOT's routing regulations.[10] For those types of packaging over which DOT retains full authority, DOT still consults with NRC in establishing standards because DOT has little staff expertise regarding nuclear safety.

NRC regulates the quality of the packages and containers used by commercial shippers of radioactive nuclear materials. However, by rule,[11] DOT has delegated to DOE authority to approve packaging and to regulate other aspects of the transport of highly radioactive materials, for which DOE is responsible under the Atomic Energy Act, not as an NRC licensee, but in its capacity as the sole producer of the nation's nuclear weapons. The DOT rule requires that DOE promulgate internal standards that are comparable to NRC's requirements. DOE has additional independent authority over aspects of high-level nuclear waste transportation under the Nuclear Waste Policy Act (NWPA), as amended.[12]

SOME REASONS LEGISLATION TO ENHANCE THE SAFETY OF NUCLEAR MATERIALS TRANSPORTATION WAS NECESSARY

The accident that would have turned the following series of events into a catastrophe did not happen, but unfortunately the facts—the container involved, the amounts of plutonium it carried, the routes it traveled and the design miscalculations that were made—are true. Thus, although the people of the United States have been spared the consequences of a transportation accident involving a release of radioactivity, it is not because the government was running a technically unimpeachable program.

The LLD-1 is a container that weighs less than 150 pounds. DOE and its predecessor agencies used it to transport up to 450 pounds of plutonium by plane and truck.

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7. 44 Fed. Reg. 38690 (July 2, 1979).

8. 42 U.S.C. section 2133; 10 CFR part 71.

9. 10 CFR part 73.

10. Office of Technology Assessment, Transportation of Hazardous Materials, U.S. Government Priting Office, Washington, D.C., 1986 (OTA), pp. 93-94.

11. 49 CFR section 173.7.

12. 42 U.S.C. section 10101, et seq. (1990).

Between 1970 and 1984, there were at least 130 truck shipments that used the LLD-1. Each truck carried up to 30 containers. In 1975, the Energy Research and Development Administration (DOE's predecessor) sought NRC certification for the LLD-1 for use by shippers other than the federal government. But the NRC did not certify the container; rather, it responded with questions about the container's structural strength and seal.[13]

In 1979, due to a finding that the container might leak its powdered plutonium oxide cargo in an accident, DOE limited LLD-1 shipments to solid plutonium. Although it also burns on contact with the air, solid plutonium poses far less of a hazard than finely powdered plutonium oxide. The latter may be plutonium's most dispersible and most dangerous form. DOE also conducted a new series of drop tests with the LLD-1 during which its support frame collapsed.[14] In response to that information, NRC questioned whether, in an accident involving a crash and fire, enough frames would buckle that nuclear criticality could result.[15] Without responding to NRC's questions about structural strength or the possibility of criticality, DOE terminated further NRC review of the LLD-1 in 1983.[16] DOE continued to make shipments in the LLD-1 until at least 1984.

Why is this important? The consequences of a serious accident involving a truck loaded with LLD-1's would be enormous. In a 1979 NRC study of worst-case transportation accident scenarios, it found that a credible extreme accident could result in the release of 15% of the contents of one LLD-1, or one kilogram of plutonium. If it occurred in a major urban area, such an accident would lead to thousands of latent cancer fatalities and billions of dollars of damage from contamination.[17] Yet, because only DOE used the LLD-1 in shipping, the transport was in essence unregulated under HMTA. The people of New York could not have kept the LLD-1 out of Manhattan.

HOW IS IT THAT THE UNITED STATES ALLOWS THE USE OF DEFECTIVE PACKAGES FOR THE TRANSPORT OF THE MOST DANGEROUS SUBSTANCE EVER CREATED?

The regulatory program for ensuring safety of nuclear materials transportation is fragmented among federal agencies. The result is serious regulatory gaps and inconsistent regulations between modes of transport or based on who is shipping.

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13. Audin, Lindsay. *A Review of the Effects of Human Error on the Risks Involved in Spent Fuel Transportation.* Prepared for the Nebraska Energy Office, 1986, rev. 1987, p. 34.

14. DOE, "Re-Evaluation of LLD-1 Package." DPST-79-217, 1979.

15. MacDonald, Charles (chief, Transportation Certification Branch, NRC). "Letter to DOE, Attn: Donald Ross." With enclosure, May 13, 1980.

16. Audin, supra, p. 35.

17. Finley, et al., *Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment.* NUREG/CR-0743. Prepared for NRC, 1979, p. 120.

For example, NRC has the responsibility of ensuring the safety of shipping-container and cask designs used for high-level nuclear waste shipments, or other large quantities of nuclear materials. DOE, the nation's largest shipper of nuclear materials, only became subject to limited NRC jurisdiction over container certification as a result of congressional directive in the Budget Reconciliation Act of 1987. Prior to that enactment, all DOE needed to do to use its casks on the road was to demonstrate to DOT that the casks meet standards "equivalent to" NRC's.[18]

The importance of the new requirement that DOE obtain NRC certification for high-level waste and spent nuclear fuel shipments is apparent from the history of DOE certifications. On at least 10 separate occasions when DOE self-certified a spent fuel cask for its own use, DOE was subsequently unable to obtain certification from NRC for their use by commercial shippers.[19] Clearly, DOE's concept of what met NRC standards differed from NRC's.

Next to the LLD-1 described above, the most distressing example of the disparity in assessment involves the MH-1A, a spent-fuel cask designed by the U.S. Army. The army used the MH-1A for 23 shipments in two casks between 1974 and 1977. DOE assumed ownership of the casks in 1977 and self-certified them for use in 1980 based on an upgraded DOE safety analysis.[20] DOE also requested certification from the NRC so that NRC licensees could use the casks. NRC sought more information because of structural questions related to the cask's ability to survive the drop test and because of questions involving a potential loss of shielding in the event of a fire.[21] DOE modified the cask to include, *inter alia*, a fire shield, and began shipments, from its Brookhaven National Laboratory on Long Island through Manhattan, in 1985. DOE made a total of 13 shipments despite the fact that NRC continued to question the safety of the cask's design. With DOE continually unable to answer satisfactorily all of NRC's concerns, DOT ultimately ordered that the cask be suspended from use.[22]

NRC CERTIFICATION

NRC has inspected few, if any, casks during production. The commission bases its certification on the paper trail of production. This record is consistent with the record for federal agencies' manufacturer inspections of other hazardous materials ship-

18. 49 C.F.R. 173.417.

19. Audin, supra, p. 33.

20. Id., p. 31.

21. MacDonald, Charles. "Letter to DOE, Attn: Reuben Prichard." With enclosure, February 24, 1983.

22. Santman, L. D. (DOT Direct Materials Transportation Bureau). "Letter to Ronald Cochran, DOE," May 23, 1985.

ping containers. In 1984, DOT inspected only 144 out of 7,000 container manufacturers.[23] Of course, no outside entity inspects DOE's cask manufacturers. This situation fosters neither careful manufacturing protocol nor public confidence.

A major part of the NRC certification design criteria is a demonstration that the cask withstand a series of four severe accidents.[24] Unfortunatley, a container may be certified as meeting the design criteria on the basis of computer-simulated accidents, rather than on the basis of actual full-scale testing with prototype casks. The rationale for this use of the computer as a replacement for physical testing would appear to be based on cost; computer runs are cheaper than actual tests with real casks that are each expensive to construct. Safety has simply not been the priority consideration.

The consequence of allowing certification on the basis of computer-simulated responses to accident stresses, or even on the basis of small-model (i.e., quarter-size) tests may be an incorrect prediction. That is a lesson this country should only need to learn once, and the occasion has already passed. TRUPACT, the container that DOE designed and built to carry transuranic (plutonium-contaminated) waste to the Waste Isolation Pilot Plant (WIPP) in New Mexico, was designed to withstand the NRC hypothetical accident conditions. It was further tested by subjecting quarter-scale models to repeated proof tests, or field verifications. However, when DOE tested a full-scale TRUPACT in 1985, the cask failed after 35 minutes of fire.[25] (The NRC certification standards require a demonstration that the cask can withstand a 30-minute all-engulfing fire, but the DOE engineers, to their credit, accepted the TRUPACT's failure at 35 minutes as an indication that redesign was necessary.)

The TRUPACT incident also highlights the awkward situation into which DOT has been placed as a result of having three agencies involved in nuclear waste transportation regulation. The NRC is generally considered to be the agency with the expertise for judging nuclear safety. But Congress expressly exempted WIPP from NRC licensing at the time of WIPP's authorization. Thus, NRC has no explicit role to play in the certification of WIPP shipping containers.[26] Consequently, the shipping containers to be used in transporting transuranic waste to the WIPP were to be certified by

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23. OTA, p. 206. The OTA study ultimately concludes that there are more current dangers and more need for reform in the hazardous materials transportation industry generally than specifically in the area of nuclear waste transport. There are two reasons why EDF does not believe that OTA's conclusions will apply in the future. First, because OTA's study never considered transuranic waste shipments, the study has no relevance to the debate over the Waste Isolation Pilot Plant shipments. Second, because OTA's conclusions are based on a historic record of a tiny number of shipments of spent fuel, in comparison to what will obtain with Monitored Retrievable Storage (MRS) or repository shipments, the study cannot be used to extrapolate future system weaknesses.

24. 10 C.F.R. part 71.

25. DOE. "TRUPACT: Transuranic Package Transporter." (A flyer.) Albuquerque, 1985.

26. Pub. Law 94-164 (1979), the authorizing legislation for the WIPP.

DOT according to that agency's requirement that all containers used in commerce be certified to meet NRC-equivalent standards.[27]

In February 1987, DOE requested that DOT change this requirement to allow DOE to use TRUPACT, a container that DOE conceded did not meet existing NRC standards. Thus, DOT was faced with deciding the safety of a container for plutonium-contaminated waste shipments even though DOT was neither responsible for adopting the underlying safety criteria nor capable, within the expertise of agency personnel, to determine the propriety of NRC's standards. In effect, DOT was asked to change the NRC determination of the necessary safety design criteria, despite DOT's lack of expertise in the area, because NRC was barred from the process. After a chorus of complaints, DOE relented and agreed to abandon TRUPACT, despite the department's multimillion dollar investment in the container. In its place, DOE began the process of designing a new container, TRUPACT-II, which the department agreed to submit to NRC for certification. Eighteen months later, after four sets of full-scale tests and numerous redesigns, DOE obtained the NRC certification, albeit limited to certain waste types and packages. Certification in hand, DOE's contractor built 15 TRUPACT-IIs, none of which measured up to NRC's standards. Again, the gap between design and real-world manufacture was shown to be substantial. Finally, however, since mid-1990 DOE's contractor has been able to produce acceptable containers.

Unfortunately, there are other reasons to remain concerned, at least one of which is due to interagency conflict. First, DOE has admitted in the draft "Supplement to the Environmental Impact Statement" (draft SEIS) for WIPP something that others have suggested for over a decade: the four NRC accident scenarios do not test for one of the most important accident forces—the "crush."[28] The draft SEIS states: "The dominant accident effect [for truck transport] is crush rather than impact."[29] As stringent as the NRC array of required drop, puncture, immersion and fire tests may be, they do not provide the information that would enable either NRC or the manufacturer to ascertain how a container would perform in a crush situation. Therefore, the fundamental underpinnings of the NRC certification process, at least with respect to truck transport of certain types of containers, has been called into question. Since DOE did not need to do a crush test to obtain NRC certification for TRUPACT-II, DOE had no regulatory incentive to perform such a test. Thus, even though DOE's own report revealed that crush forces would be the critical test for TRUPACT survival in the event of a truck accident, DOE did not perform a crush test on TRUPACT-II prior to applying for NRC certification.

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27. 49 C.F.R. part 173(d).

28. DOE. "Draft Supplement to Environmental Impact Statement: Waste Isolation Pilot Plant." DOE/EIS-0026-DS (WIPP draft SEIS), vol. 2, p. D-65.

29. Ibid.

CASK INSPECTION

Neither DOT nor NRC have credible cask inspection programs. The overlapping nature of the agencies' authorities once again leads to a situation where meaningful enforcement falls through the cracks. The extreme deficiencies in the system compelled Congress expressly to direct not just that DOT shore up its inspection staff, but to specify the additional number of inspectors Congress wanted DOT to hire, as explained in more detail below.

At DOT, the total number of inspectors responsible for hazardous materials transport decreased during the early 1980s. In 1985, there were only the equivalent of 110.5 inspectors for all hazardous materials, including nuclear waste, shipped by all modes.[30] Not to be outdone in minimalism, NRC has a grand total of six inspectors, out of a total of 80, who devote their time to the inspection of nuclear waste shipments.[31] Absent a dramatic increase in federal funding (which would be appropriate given the upcoming quantum leap in the number of shipments that will be associated with WIPP's opening), cask safety inspections will continue to be done, if at all, by state officials, most likely at ports of entry. Although these officials may have the authority to take a container out of service, they have no power over cask construction or maintenance.

Adding to these concerns regarding cask inspection is the fact that, although there have been relatively few shipments in the last two decades, the inspectors on the job have often missed problems that occurred. Look, for example, at what happened to the NAC-1 spent nuclear fuel casks. Seven were built in 1974. In a two-week period during June 1977, inspectors discovered five open vent valves and one open drain valve among three casks that had been used in approximately 150 shipments. One NRC inspector concluded that these valve failures resulted from normal truck vibrations during transport, because the valves had not been adequately tightened originally—possibly a result of incorrect installation instructions.[32] These casks had been used for several years, still, no one—including DOT, which has primary responsibility to ensure safe transport—had discovered the problem. The explanation may be that then-current NRC regulations required an inspection prior to, but not after, shipment.[33]

There have also been defects that resulted from a lack of inspection (and/or of quality assurance procedures) during cask manufacture. Again, using the NAC-1s as one example: at the time of their fabrication, the NAC-1's lead shielding was poured in a molten state into the space between two concentric shells and left to cool. Because the shielding in one of the casks was thinner than desired in places, the manufacturer welded copper plates to the outside of the steel-shelled casks. This was an

30. OTA, supra, p. 209.

31. Id., p. 211, and Audin, supra, p. 52.

32. Head, J. T. "Letter to Director of Nuclear Materials Safety, NRC." With enclosures, July 12, 1977; and Burstein, Sol. "Letter to Director of Nuclear Materials Safety." July 21, 1977.

33. Audin, supra, p. 42.

unauthorized response that went unnotice during 84 shipments, until 1979 when a purchaser of the cask discovered the plates.[34] The presence of copper next to steel can lead to a lowered melting temperature at the point where the two metals are in contact. A loss of lead shielding could allow lethal doses of radiation to escape through the walls of a cask, even absent a breach of the cask's outer integrity.[35]

The NAC-1's buyer also discovered in 1979 that the inner cask cavity shell of this same cask, along with that of a second NAC-1, was bowed. Although the purchaser notified NRC of the casks' condition, NRC allowed an additional four shipments of spent fuel before suspending the casks from use. Neither cask had been in a recorded accident. Thus, the bowing resulted either from normal use that had occurred during the five years the casks were on the road or from construction which did not precisely follow the NRC-approved design plans and specifications.[36] In an accident, this bowing could have led to buckling of the inner cavity that could then have damaged the fuel rods or forced the pressure relief valves open.[37] Neither DOT nor NRC inspectors discovered the problems during the casks' five years on the roads.

The NAC-1 was not the only cask that was improperly constructed. The 67-Ton Rail Cask, built in 1962, was used in Sandia National Laboratory's 1978 fire test. It was designed to withstand a 60-minute fire (as opposed to the 30-minute fire that NRC currently requires). After 100 minutes, observers saw a white cloud rise from the cask, so they stopped the fire. The ensuing inspection of the cask disclosed: (1) that the outer shell had cracked, allowing lead shielding to vaporize, (2) that no holes had been drilled into which the molten lead could have expanded, as was required in the cask design, and (3) that the cask had been completed with improper welds that involved incorrect materials and excessive welding temperatures. A loss of lead shielding would subject people to an increase in radiation dosage through cask walls, even without an actual release of radioactive material. Again, neither NRC nor DOT personnel observed any of these defects during the cask's 16-year life.[38]

These real-world occurrences undercut the agencies' rosy predictions regarding nuclear materials transportation accidents as well as their assurances that their "close cooperation" ensures that the fragmented regulatory program will function effectively.

NRC released a study in May 1987 regarding the radiological effects of an accident involving a spent fuel cask. The study concludes that NRC's 1977 report on this same topic overestimated the likely radiological impacts of a serious spent-fuel accident.[39] (In 1977, NRC predicted that an accident in a densely populated urban area like New York would result in $2 billion in damage even if the radiation release was not enough

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34. Rollins, Jack. "Letter to C. E. MacDonald (NRC)." April 12, 1979; and NRC Inspection Report No. 99900331/79-01.

35. Audin, supra, pp. 43-44.

36. Id., p. 44.

37. Ibid.

38. Id., pp. 38-39.

39. 51 Fed. Reg. 17862 (May 12, 1987).

to cause any immediate deaths.[40]) Yet, in the 1987 study, NRC assumed the use of perfectly constructed, perfectly maintained and perfectly operated casks that performed as designed.

This assumption alone renders the revised study's conclusions almost irrelevant for use in predicting the likelihood of an accident in the real world, where such flaws frequently occur, as is demonstrated by the history of the casks themselves. It is difficult to factor human error, particularly in manufacture or maintenance, accurately into a probabilistic risk analysis. For example, the classic fault-tree analysis of the Three Mile Island accident yields a probability of such an incident occurring once during three million reactor-years. It actually occurred after 500. Similarly, fault-tree analysis predicts that a Chernobyl-type incident should occur one in 10 million reactor-years; it occurred after 300.[41] Real-world factors and the problems they pose for risk analysis should have been noted by NRC in its study. NRC and DOE (which relies on NRC conclusions) should have noted that uncertainty associated with human error could increase the probability of an accident occurring and/or the adverse consequences of an accident by several orders of magnitude. Neither agency includes this caveat.[42]

With regard to the solace one might otherwise take in the agencies' proclamations that their close cooperation vitiates any defects caused by the legal scheme's fragmentation, these incidents show one can find no such comfort. Thus, to the extent that HMTUSA relies on increased opportunities for interagency coordination (as described below), it may not solve the system's existing regulatory inadequacies.

ROUTING

DOT has established suggested highway routes for shipments of nuclear materials, but it is waste carriers, without regulatory oversight, who choose the final route for a shipment.[43] Rail transport, which DOE expects to be the primary future mode for high-level nuclear waste shipments, is under even less control. DOT has not yet taken the first step to establish preferred routes or minumum operator training requirements for rail shipments. Similarly, DOT has not yet promulgated rules relating to the transportation of nuclear materials by barge. DOT's lack of expertise in the field of nuclear safety will again hamper the agency in making sound decisions about the relative safety of routes and modal mixes for the major nuclear waste campaigns that are expected to occur in the next generation. As described below, Congress has taken some steps in HMTUSA to avoid having DOT make ill-considered decisions on these

40. Nuclear Regulatory Commission. *Final Environmental Impactaemnt on the Transportation of Radioactive Material by Air and Other Modes.* NUREG-0170, (1977).

41. Audin, supra, pp. 54-55.

42. NRC. *Shipping Container Response to Severe Highway and Railway Accident Conditions.* NUREG/CR-4829 (1987); WIPP draft SEIS.

43. 49 C.F.R. parts 173.7(b) and 177.806(b).

matters. However, unless DOT has more experienced staff in areas such as health physics, the congressional action may not be enough.

Pending congressional authorization and New Mexico permitting, DOE is ready to begin testing the WIPP in New Mexico using transuranic waste. Ultimately, WIPP will receive 1,400 truckloads of transuranic waste each year. Most of these waste shipments will originate in Idaho, Washington, or Colorado, but there are 23 WIPP shipment corridor states. DOE has established an upper limit of 12,000 curies of radioactivity per truckload.[44] If DOE builds a monitored Retrievable Storage (MRS) facility for the temporary storage and possible consolidation of high-level nuclear waste bound for that permanent repository, utilities will ship between 2,500 and 3,000 metric tons of uranium during the facility's full-scale operations. Under the Budget Reconciliation Act of 1987, shipments could begin shortly after the turn of the century.

If DOE can open the Nevada high-level waste repository, it could also accept 3,000 metric tons of spent fuel, on the average, each year.[45] By contrast, there has been only slightly more than that amount of spent nuclear fuel shipped *in total* since 1972.[46] Depending on the modal mix of shipments, as many as 43 states could be corridors for high-level nuclear waste shipments.[47] A shipment of spent nuclear fuel—assuming that there is one metric ton of uranium per shipment, the rods are not consolidated, and the fuel has been out of the reactor for 10 years—would contain approximately 700,000 curies of radiation.[48] If containers with similar capacity to those in use today are used, DOE would be putting 6,800 truck shipments or 860 train shipments on the road annually. However, DOE estimates that a new generation of casks will be built by the time the repository opens, which would cut these numbers approximately by half.

SUGGESTED REFORMS

The OTA study cited above concluded that Congress had to clarify the duties and responsibilities of the five agencies it identified as most involved in regulating the transport of hazardous materials: DOT, NRC, DOE, EPA, and the Federal Emergency

44. Channel, James et al. *Adequacy of TRUPACT-1 Design for Transporting Contact-Handled Transuranic Wastes to WIPP*. EEG-33, State of New Mexico, Santa Fe, 1986, p.v.

45. DOE. *Environmental Assessment.* Vol. 2, DOE/RW-0069 to 0073, Washington, D.C., 1986, p. A-31.

46. OTA, supra, p. 91.

47. Western Interstate Energy Board. *Spent Nuclear Fuel and High-Level Radioactive Waste Transportation.* (Draft), Denver, Colorado, p. 37-53.

48. Lipschutz, Ronnie. *Radioactive Waste: Politics, Technology and Risk.* Union of Concerned Scientists, Ballinger Publishing Co., Cambridge, Mass., 1980, p. 43. External exposure to three curies of cesium-137, one of the major radionuclides contained in spent fuel, would be considered a lethal dose. Id., pp. 15 and 26.

Management Agency (FEMA). EDF advocated that Congress strengthen and streamline federal authority in four specific areas:

1. To institute a comprehensive inspection program of carrier terminal and materials/waste storage facilities, Congress should transfer DOT's Bureau of Motor Carriers and the Materials Safety Branch to the National Highway Traffic Safety Administration. This reconstituted federal entity could then focus on inspection of carrier terminals and materials/waste sources to ensure safe loading of the materials, as well as compliance with the industrywide maintenance and safety standards mentioned below.

2. Congress should require that any comprehensive DOT regulation for carriers encompass such diverse matters as minimum training requirements and standards for rail, truck and barge operators, as well as for all waste-handling personnel who must load or unload containers from the carrier vehicle; mode- and industry-specific maintenance protocols and standards; and a national registration system.

3. To ensure safe design, manufacture and ongoing use of containers carrying nuclear materials, Congress should direct NRC to require, in addition to its present mandates: (a) tests to show how the container would respond to all likely accident forces (including "crush" forces); (b) the physical testing of as-built casks to destruction; and (c) the presence of inspectors during cask manufacture.

4. To prepare for the massive nuclear materials shipping campaigns, which were EDF's greatest concern, and one of which was imminent, EDF asked Congress to direct DOT to develop thorough, all-encompassing cost and risk assessments as well as a comprehensive analysis of least-risk alternatives for modes and routes for nuclear materials transportation. Such effort should be conducted in a manner that assures full disclosure of methodologies, peer review and public participation. EDF advocated this requirement because DOT has never done a comprehensive environmental analysis or risk assessment of its highway routing rules as they apply to nuclear materials transportation. We asked that DOT's effort be in addition to the planning that DOE would also be doing prior to starting shipments.

In addition, to help state, tribal and local governments better regulate routing and shipments through their jurisdictions, DOT (in cooperation with the NRC) should develop true worst-case scenarios for accidents. Local governments could then use these as a basis for developing detailed analyses of their needed emergency response capabilities and for identifying where those capabilities are currently lacking.

HMTUSA: THE ACTUAL REFORMS

Congress responded in several different ways to the criticisms regarding the federal agencies' lack of coordination in regulating the transportation of hazardous materials. With respect to the OTA plea to clarify the various agencies' responsibilities, Congress provided for the secretary of transportation to take the lead in formulating the following programs, but in each case to coordinate with other appropriate federal agencies.

1. In consultation with the EPA administrator and secretary of labor, to ensure that training requirements for hazardous materials employees governing safe loading, unloading, handling, storing, shipping and emergency preparedness do not conflict with OSHA and EPA regulations.[49]

2. To obtain from EPA such information as the secretary deems necessary to implement the new registration program.[50]

3. In consultation with DOE, NRC, and others, to study the comparative safety of using dedicated versus ordinary trains to ship high-level nuclear waste and spent fuel.[51]

4 To delegate to the EPA administrator, the secretaries of labor and energy, the executive director of the NRC, the director of FEMA, and the director of the National Institute of Environmental Health Sciences (NIEHS), for review and recommendation, applications for grants to states to develop emergency plans under SARA Title III; and to develop a curriculum for training emergency responders.[52]

Each of these efforts represents a new initiative on the part of the secretary for the regulation of hazardous materials transportation. Thus, there remains a significant question regarding whether HMTUSA clarified existing responsibilities among the agencies. It is clear, however, from the manner in which Congress structured the new programs and regulatory requirements, that the secretary of transportation, and thus DOT, is to take the lead and the lion's share of the responsibility in regulating both hazardous materials in transit and the activities, qualifications and training of all employees and employers involved in transporting such materials in commerce.

There were suggestions that an amended HMTA require DOT to adopt comprehensive regulations covering training requirements for operators of all modes

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49. 49 U.S.C. section 1805(b)(3).

50. 49 U.S.C. section 1805(c)(2).

51. 49 U.S.C. section 1813(a).

52. 49 U.S.C. section 1814A(f) and (g).

and for waste-handling personnel; maintenance protocols; and to establish a national registration system. Congress responded to these suggestions with HMTUSA section 106. This section requires training regulation and registration. It also sets up a permit program for carriers.

Congress did not change the requirements for nuclear materials container certification in HMTUSA. However, amendments to the Nuclear Waste Policy Act adopted after Congress' 1987 hearings on HMTA amendments did make some changes. DOE was required to transport high-level nuclear waste to disposal sites under the NWPA amendments. In addition, it was required that transuranic waste bound for WIPP be carried in NRC-certified containers. Thus, Congress eliminated the most disturbing self-certification provisions of the old system.[53]

With regard to planning for the major nuclear materials shipping campaigns, Congress directed the secretary (in section 116) both to do a modal study and to conduct a rulemaking hearing for adoption of regulations applicable to rail transport. Regulation would require the same level of safety for rail as is currently provided in DOT's highway rule governing nuclear materials transport.

The one area that Congress did not address was the need to institute an inspection program for carrier terminal and materials storage facilities. However, Congress did mandate that DOT add 30 inspectors to the number employed in 1990, 10 of whom are specifically designated to conduct point-of-origin inspections for nuclear materials shipments and any other possible nuclear materials inspections. Thus, Congress addressed one of the most critical and glaring findings of the OTA study.

REMAINING GAPS AND PROBLEMS; NEW AVENUES FOR COLLABORATION

Clearly, the new HMTUSA is streamlined, with overarching authority vested in the secretary of transportation for regulating hazardous materials shipments. If the agencies can in fact consult in a productive manner, and if DOT can use the expertise of its sister agencies productively and fill in the gaps that remain in DOT's own employees' areas of expertise, HMTUSA should result in far better regulation at the federal level. However, with regard to some of the cooperation that HMTUSA envisions, Congress does not appear to have taken into account that they have asked agencies with very different types of responsibilities, motivations, and fiscal incentives to coordinate with one another.

For example, it may make sense for DOT to fashion regulations in consultation with other regulatory and enforcement agencies such as EPA or the Department of Labor. But coordination with DOE, which is part of the regulated community under the act, may prove difficult, at best, and certainly subject to public skepticism. While DOE's agenda may be different from DOT's, DOE's incentive to share information towards the development of more stringent regulations for carriers is clearly at odds with DOT's incentive.

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53. 42 U.S.C. 10175(a).

Coordination with agencies such as FEMA and NIEHS will tend to be less of a problem. These agencies do not have direct enforcement or regulatory authority. In addition, they are themselves not regulated under the law. For both these reasons, they will tend to be more inclined than DOE to cooperate with DOT.

To the extent that HMTUSA gives any of these agencies a significant role in developing programs, the statute does not resolve the inherent and underlying conflicts that existed prior to its enactment. Moreover, agencies without direct statutory duties need incentives to induce their timely cooperation. Congress provided DOT the ability to share money with these agencies for the development of some of the new initiatives required by law, and money is always a good inducement. But, because of the sums involved, and due to the fact that in some cases no money appears to be directly allocated to these other agencies, cooperation is not necessarily ensured. In two years, after DOT's release of the major deliverables (training programs and regulations), it will be more apparent whether the congressional carrots have successfully induced the real agency cooperation that has been lacking in this area for so long.

Fundamentally, the success of interagency coordination depends on how well the agencies involved can suppress what may be conflicting institutional goals and motivations to advance a common good, established as congressional policy through passage of legislation such as HMTUSA. If the overarching goal of HMTUSA is the uniform safe transport of hazardous materials, including nuclear materials, then the key to interagency coordination will be for DOT, DOE and NRC to set aside their institutional biases and duties that conflict with this goal. Developing a seamless, coherent and sensible framework for regulating nuclear materials transport in all modes has, to date, eluded these agencies. HMTUSA may have provided a structure to make this goal achievable. However, critical to its success will be the type of culture change to which Secretary of Energy James Watkins constantly refers in his efforts to reform DOE. In other words, the personnel who do the interagency coordinating must want the effort to work. And this factor is not a matter Congress can legislate. It is a matter of will and desire with which agency directors must imbue their staffs. Only with that component can the executive branch achieve Congress' HMTUSA goals.

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AN ECONOMIC REVIEW OF MONITORED RETRIEVABLE STORAGE FOR SPENT NUCLEAR FUEL

Geoffrey Rothwell

ABSTRACT

Storage capacity for spent nuclear fuel at commercial reactor sites is filling up. Electric utilities must either increase on-site capacity or ship their waste to other facilities. This paper reviews federal transport, storage, and disposal policy. It focuses on a recent report of the Monitored Retrievable Storage (MRS) Review Commission that analyzes medium-term spent nuclear fuel transport and storage alternatives. Because of the political constraints imposed on the Commission, it was unable to make reasonable assumptions regarding future transportation costs and risks. The paper concludes with recommendations for the Department of Transportation's future "Dedicated Trains" and "Mode and Route Study" for spent nuclear fuel.

INTRODUCTION

The currently operating light water reactors in the U.S. will generate 87,000 metric tons of highly radioactive waste during their lifetimes. This spent nuclear fuel will be contained in more than 220,000 bundles known as fuel assemblies. Until the late 1970s the industry assumed that the waste would be recycled through chemical reprocessing. Because of concern over nuclear proliferation and reprocessing economics, federal reprocessing plans were discontinued in 1977. Congress debated the issue for five years before the passage of the Nuclear Waste Policy Act of 1982 (NWPA). This act called for the selection and review of a long-term repository site that would safely store the waste for at least 10,000 years. During the 1980s, shorter-term solutions were proposed. One of these became known as Monitored Retrievable Storage (MRS). The 1987 Amendments to the Nuclear Waste Policy Act called for a commission to assess the feasibility and necessity of Monitored Retrievable Storage. This

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paper reviews the commission's cost and transport assumptions in anticipation of the Department of Transportation studies required under the Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA).

The first section presents the problems associated with spent nuclear fuel, including its high toxicity. Section two discusses congressional response to the mounting commercial nuclear waste problem, which has been focused recently on transportation issues. In the third and fourth sections, I discuss the Monitored Retrievable Storage Review Commission's report, *Nuclear Waste: Is There A Need for Federal Interim Storage*? I find the report lacking in key areas because of its inability to assess specific interim storage sites. The final section discusses recommendations for future studies.

SPENT NUCLEAR FUEL

Several industries generate radioactive waste. These include nuclear power, nuclear weapons-related defense, nuclear medicine, and nuclear research. But these industries do not contribute equal amounts of radioactive waste, characterized by radioactivity and volume (see OTA 1989, pp. 84 and 88). (Radioactivity is measured in curies; one curie is equivalent to the radioactivity of one gram of radium.) Commercial nuclear reactors have generated 94% of the current cumulative radioactivity in the United States (See OCRWM, 1987, for lists of isotopes and curies of each isotope in spent fuel from each reactor.) Because of the high concentration of radioactivity in its waste, commercial nuclear reactors contribute little to the total volume. Also, because of its high radioactivity, spent nuclear fuel poses unique transportation problems as a hazardous material.

Although the number of curies is a convenient measure of radioactivity, it does not adequately describe the toxicity of spent nuclear fuel. A measure of the impact of radiation on human tissue is the rem (roentgen equivalent in man), where the roentgen measures ionization exposure. Current regulations (10 CFR 20.101) limit personnel at nuclear power plants to 1.25 rems per quarter, 5 rems per year, and a long term dose equal to 5 x (Age - 18).[1] There is an active debate in the health physics literature regarding the relationship between rems and fatal cancers. The most important factor is the age of the exposed individual. Younger people are more sensitive to the ill effects of radiation than older people. In a population with a mix of ages, estimates of the number of fatal cancers range from one per 376 whole-body rems (Goffman 1990) to 2,500 whole-body rems (EPA 1989).

Further, there are several types of radiation, including emissions of alpha and beta particles and gamma rays. Each of these types of radiation affects living tissue in different ways. For example, compare Plutonium-239 with Cesium-137. Plutonium is an alpha emitter; cesium emits beta particles and gamma rays. Because alpha

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1. These limits do not imply that these doses are safe. In fact, they might double the risk of cancer. See National Academy of Sciences (1989). Note: the 5 rem limit is rarely exceeded in nuclear power plant operations.

particles cannot travel through human tissue, an external exposure of one day to one curie of plutonium produces only 0.38 rems. Internal exposure (through inhalation or ingestion) of one microcurie (one-millionth of a curie) produces 110 rems. Because beta particles and gamma rays can penetrate tissue, these types of radiation move rapidly through the body. The external exposure of one day of one curie of cesium produces 137 rems, but internal exposure of one microcurie produces only 0.032 rems. (For an extended discussion of these topics, see Kassen and Petti, 1988, Appendix A.) Therefore, to determine the toxicity of spent nuclear fuel all isotopes must be identified and the exposure must be defined.

There are 108 operating reactors in the United States. Of these, 35 are boiling water reactors (BWR), manufactured by General Electric. The remainder are pressurized water reactors (PWR), manufactured by Babcock & Wilcox, Combustion Engineering, and Westinghouse. In the central core of each reactor are bundles of fuel rods (assemblies) containing enriched uranium.[2]

Each year or so reactors are refueled by replacing spent fuel (typically one-fourth to one-third) with fresh fuel. Fuel assemblies in BWRs are smaller than those in PWRs. Metric tons of heavy metal (MTHM), i.e., uranium, have averaged 0.18 in BWR assemblies and 0.42 in PWR assemblies. The composition of fuel changes as it releases its radioactive energy and heat (measured by thermal megawatts [MWt]) in the reactor. Spent nuclear fuel is composed of dozens of activation and fission products, most of which decompose rapidly, and over a dozen isotopes of elements heavier than uranium (transuranic), including plutonium, that decompose slowly. The half-life of plutonium is 24,400 years, i.e., after 24,400 years one half the plutonium will have decayed.

Each reactor has a temporary storage facility for the spent fuel. The assemblies are stored in pools of water (wet storage), because of water's insulating properties. These pools will be filled at half the reactors by 1995.[3] To continue operating, reactor operators must either expand their capacity or send their spent fuel to other facilities. Capacity expansion can be done by reracking the pools (refitting pools with racks that hold more fuel assemblies), by building more pools, or by investing in dry storage facilities.[4] There are several dry storage technologies in use at U.S. reactors.

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2. Uranium has two natural isotopes: U235 and U238, where the radioactive isotope (U235) is less than one percent. Through mechanical means, the concentration of U235 is increased to approximately three percent for reactor fuel. Nuclear weapons contain highly enriched uranium with concentrations of U235 above 95%.

3. See "Status of Spent Fuel Storage Capability," in Section 3 of the Nuclear Regulatory Commission's *Licensed Operating Reactors* (NUREG-0020, published monthly).

4. Dry storage involves a double handling of the fuel because fuel must be reloaded for transportation. Rod consolidation is another option that involves removing fuel rods from the fuel assemblies to pack rods into tighter bundles. The utilities that have experimented with this procedure prefer dry storage. See MRS Review Commission (1989, p. 41).

At the Surry power plant (in Virginia), fuel assemblies are stored in metal casks; each cask has its own shielding and cooling system. At the Robinson and Oconee power plants (both in South Carolina) fuel is placed in stainless steel containers and stored inside concrete bunkers. (See MRS Review Commission, 1989, p. 23). Away-from-reactor storage is limited to one installation in Morris, Illinois. Congress has discussed other storage sites for over a decade.

CONGRESSIONAL RESPONSE

In 1982 Congress passed the Nuclear Waste Policy Act (PL 97-425), establishing a comprehensive program to dispose of high-level radioactive waste.[5] Both the House and the Senate worked on nuclear waste bills for several years. In 1979 (the 96th Congress) the Senate Energy Committee approved legislation requiring the Department of Energy (DOE) to designate a site for medium-term monitored storage by 1980. The Atomic Energy Commission (AEC) proposed a similar plan in 1972, but it was withdrawn in 1975 by the Energy Research and Development Administration (a successor to the AEC and a predecessor to the DOE).[6]

There were attempts in the first half of the 97th Congress to reconcile competing nuclear waste bills. The most comprehensive bill (HR 3809), which would eventually become PL 97-425, was introduced by the chair of the House Interior Committee, Morris Udall (D-Arizona). Congress reconciled Senate and House bills on December 20, 1982. Major provisions of the Nuclear Waste Policy Act (NWPA) of 1982 included:

1. A recommendation by the secretary of energy of three geologically-sound, long-term storage sites by January 1, 1985; a submission to Congress by the president of one long-term storage site by March 31, 1987; and a review of the site by the Nuclear Regulatory Commission by January 1, 1989

2. A determination by the secretary of energy regarding the need for and feasibility of medium-term monitored retrievable storage by June 1, 1985

3. A provision that the bill would not affect existing federal, state, or local laws governing transportation

The NWPA also established a Nuclear Waste Fund to cover spent nuclear fuel storage and disposal expenses (implemented currently as a one mill, $0.001, charge to

5. Much of this discussion is from the *Congressional Quarterly Almanac* 1979, pp. 699-701; 1980, pp. 494-502; 1981, pp. 455-59; 1982, pp. 304-10; 1987, pp. 307-11; and 1990, p. 3599; and from the MRS Review Commission (1989, Appendix F).

6. In 1970 the AEC proposed locating a repository in old salt mines near Lyons, Kansas. This site was abandoned by 1972 because of geological limitations. See MRS Review Commission (1989, p. F-1).

customers for each net kilowatt-hour of electricity). The DOE administers the fund. Data on fuel discharges is collected by the Energy Information Administration (EIA), see EIA (1990).

In 1987, to reduce federal spending on exploring the geology of long-term storage sites, Senate Energy Committee Chair J. Bennett Johnston (D-Louisiana) introduced legislation to limit exploration to one site. In the conference committee to reconcile the deficit-reduction spending bill, provisions were adopted constraining the DOE from selecting a site that lay below an aquifer. The only site that did not lie below an aquifer was Yucca Mountain, Nevada. Further, as a compromise to legislators from states that were candidates for MRS facilities (e.g., Tennessee[7]), an earlier amendment was adopted to revoke proposed sites for MRS facilities and to appoint a three-member commission to investigate the need for medium-term storage. When passed on December 21, 1987, these changes to NWPA became the Nuclear Waste Policy Amendments Act (NWPAA) of 1987 (PL 100-203). The NWPAA limited the size of an MRS facility, linked MRS construction and operation to the licensing and construction schedule of the long-term repository, required NRC certification of all MRS and repository sites, and directed the MRS Review Commission to compare spent nuclear fuel disposal systems with and without an MRS. (See 42 USC § 10163 and § 10168(d).)

Prompted by the planned opening of a Department of Energy facility for weapons-related waste, i.e., the Waste Isolation Pilot Plant, and ambiguity associated with the lack of authority regarding interstate transportation of nuclear waste, several bills were introduced in the 100th Congress. Among these bills was HR 3836, "[t]o amend the Hazardous Materials Transportation Act to prescribe procedures for the transport of nuclear materials." The Subcommittee on Energy and the Environment of the House Committee on Interior and Insular Affairs held a hearing on May 12, 1988, to review nuclear waste transportation.[8] (See U.S. Congress, House, Interior, 1988). (Also see U.S. Congress, House, Energy, 1985, for an earlier discussion of these issues.)

Morris Udall (D-Arizona), chair of the Energy and Environment Subcommittee, outlined the purpose of the hearings (p. 1):

> Since Congress passed the Nuclear Waste Policy Act in 1982, debate has focused on finding a site for the permanent repository. The next major hurdle, however,

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7. Opposition to the location of an MRS in Tennessee was vocal throughout the 1980s. For a discussion of the legal basis for this opposition, see Brown (1985), particularly, section 4, "Comments on the United States Department of Energy's Proposal to Locate a Monitored Retrievable Storage Facility in Tennessee."

8. Other bills considered at the hearing were H.R. 1649, "[t]o establish a requirement that no person may offer any high-level radioactive waste for transportation in interstate commerce unless licensed for such offering by the Nuclear Regulatory Commission" and H.R. 4041, "[t]o require the Secretary of Energy, when transporting certain radioactive materials, to use the packages that the Nuclear Regulatory Commission has certified for that purpose."

> will be shipping waste from over 100 power plants throughout the country to the permanent repository. No one wants a repository in his backyard, as nearly as I can discover, but no one wants nuclear waste trucks driving down his street either. While only two or three States will wind up with repositories, nearly every State will have nuclear waste passing through it.
>
> Shipments to the permanent repository or even the monitored retrievable storage facility probably won't begin before the turn of the century but it is wise to begin planning ahead. We will need to develop adequate shipping containers, plan routes, train public safety officials, upgrade roads, bridges, and railroads, and work out appropriate relationships between Federal, State, and local officials.

Unfortunately for the debate surrounding nuclear waste transportation, none of these bills were reported out of committee. However, HMTUSA (PL 101-615, November 16, 1990) does address nuclear waste transportation in section 15:

> (a) Railroad Transportation Study. The Secretary . . . shall undertake a study comparing the safety of using trains operated exclusively for transporting high-level radioactive waste and spent nuclear fuel (hereinafter in this section referred to as "dedicated trains") with the safety of using other methods of rail transportation;
>
> (c) Mode and Route Study. The Secretary shall, within 12 months after the date of enactment of this section, undertake a study to determine which factors, if any, should be taken into consideration by shippers and carriers in order to select routes and modes which, in combination, would enhance overall public safety related to the transportation of high-level radioactive waste and spent nuclear fuel.

A similar study was undertaken by the Monitored Retrievable Storage Review Commission. I review the MRS study to raise issues that should be addressed in the "Dedicated Train Study" and in the "Mode and Route Study." (These studies were begun in late 1992.)

MONITORED RETRIEVABLE STORAGE

On November 1, 1989, the MRS Commission published its findings: "The net cost of a waste management system that includes an MRS would be lower than previously estimated because of delays that have already occurred in the expected date of repository operation, and the likelihood of further slippages of that date" (p. xv, MRS Commission Report, 1989). Further, the commission concluded there were no other factors, such as safety, that would significantly influence either the costs or the benefits. The commission recommended there be no linkage between medium- and long-term storage and that two other types of shorter-term storage be constructed: one for emergencies, such as an accident at a nuclear power plant, and one for away-from-reactor storage (i.e., federal storage similar to that at reactor sites). Finally, "Congress should reconsider the subject of interim storage by the year 2000 to: (a) take into account uncertainties that exist today and which might be resolved or clarified within 10 years, (b) consider developments which cannot be anticipated today, and (c) evaluate the experience with the two facilities recommended above" (p. xvii). This section discusses the models and assumptions of the commission generally. Section 4 focuses on transportation issues.

The MRS Commission bases its findings primarily on two models developed by contractors to the commission and to DOE. The MRS Review Commission's Analysis of System Risk and Cost (MARC) model is a linear, constrained- optimization model developed by ICF Technology Incorporated. It can minimize the total lifetime cost or radiation exposure, or a linear combination of cost and exposure, associated with a spent nuclear fuel management system. MARC is based on Battelle's TRICAM (Transportation Risk and Cost Analysis Model). Cost information was generated by the Nuclear Waste Cost Data Base and Simulation Model (WACUM) developed by Golder Associates, Inc. Risk information came from two sources: (1) Sandia National Laboratory's RADTRAN (Modified RADTRAN III) computer model, which generated transportation exposure information, and (2) a letter from ICF Technology Incorporated to the MRS Review Commission, dated September 14, 1989, which presented information on radiological risks associated with waste management activities modeled in MARC (see p. G-7 of MRS Commission Report, 1989). Each of these models and the underlying assumptions requires discussion.

First, although MARC allowed the commission to specify different linear objectives, MARC does not allow specific tradeoffs between cost and exposure. Models calculate *either* cost *or* exposure for different waste management alternatives. Linear combinations of cost and exposure were considered, but the MARC model assumes that technologies are fixed. It attempts to determine the optimal movement of spent nuclear fuel from wet storage to dry storage to the MRS facility (if there is one) to a repository. Therefore, the commission could not consider increases in cost for technologies to decrease exposures for specific activities. Nonlinear tradeoffs between cost and exposure were not considered.[9]

Second, cost information for each activity, i.e., system development, transportation, reactor storage, MRS, and long-term repository, was: "derived at a week-long probability encoding workshop held at Golder Associates, Inc., offices, Redmond, Washington, April, 1989. All of the unit costs in the encoded data base are expressed probabilistically, generally in terms of the minimum, most likely, and maximum possible values" (p. G-8, MRS Report) Cost categories include D&E (design, engineering, testing, and licensing costs); capital (the total cost of system structures and equipment); fixed operating (the annual cost of the system); and variable operating (costs directly related to the quantity of spent nuclear fuel processed in each

9. A more sophisticated siting and routing model is presented in ReVelle, Cohon, and Shobrys (1991). This model too does not consider nonlinear technology-risk tradeoffs.

year). All costs are expressed in thousands of constant 1989 dollars. Because "[n]o allowance is made for inflation" (p. G-8), the commission implicitly assumes a *real* discount rate of 4% (pp. 71-74, MRS Report), i.e., all prices rise at the same rate over the planning horizon. I explore this assumption as it relates to transportation cost inflation in the next section.

Third, the commission assumes that "each 10,000 person-rem will produce four cancer fatalities" (p. 29, MRS Report). A person-rem is the product of the number of rems and the number of persons exposed, i.e., a whole-body cancer-dose of 2,500 rems per cancer. This is based on the Environmental Protection Agency's Proposed National Emission Standards for Hazardous Air Pollutants for Radionuclides (EPA, 1989). The commission assumes that all persons living within a 50-mile radius of the MRS facility, as well as transportation workers, are equally exposed to radiation during transportation.

But cancer fatality calculations depend crucially on individual exposure, not on exposures to groups of individuals. Therefore, specific populations must be considered. However, because of the political constraints placed on the commission, it could not consider a specific MRS site. A hypothetical location was postulated. This was done by dividing the United States into six regions: "The risks from the two eastern-most centroids were averaged to form a composite location" (p. G-11, MRS Report). ("In the cost analysis, the MRS was assumed to be located at the centroid of the Southeastern region" [p. G-11]). Because of the lack of a specific site and the wide variation between dose and cancer rates in the health physics literature, cancer deaths associated with different spent nuclear fuel management systems could vary more widely than the commission estimated.

Under their assumptions, the commission finds little difference between the cost or exposure levels between the no-MRS, the linked-MRS, and the unlinked-MRS options. Similar conclusions are made for mode choice for the transportation of spent nuclear fuel.

TRANSPORTING SPENT FUEL

According to the Office of Civilian Radioactive Waste Management database (OCRWM, 1987), assuming no new orders for reactors, by the year 2020 there will be more than 220,000 fuel assemblies to transport. These will be shipped eventually from reactors to short-, medium-, or long-term storage facilities in protective casks by truck and rail. To shield against radioactivity and heat, these casks must be extremely heavy. For example, a typical truck cask weighs 32 metric tons (MT) and rail casks weigh between 70 and 120 MT. Current designs for truck casks carry 4 PWR and 9 BWR assemblies and rail casks carry 21 PWR and 52 BWR assemblies. Therefore, during the next 30 to 60 years, there will be thousands of cask trips involving millions of cask and shipment miles.

Two federal agencies regulate spent nuclear fuel transport: the Department of Transportation (DOT) with authority through the Hazardous Materials Transportation Act and the Nuclear Regulatory Commission (NRC) with authority through the

Atomic Energy Act. The DOT sets standards for routing (it has done so for trucking only, see HM164),[10] vehicle safety, and driver qualifications for controlled quantity shipments.

To avoid overlapping authority, under a Memorandum of Understanding (44 FR 38690, July 2, 1979), DOT defers to the NRC in setting standards for shipping casks. Regulations at 10 CFR 71 specify cask standards. Levels of external radiation cannot exceed 200 millirems per hour on the surface of the cask and cannot exceed 10 millirems per hour one meter from the cask. Further, casks must meet the following four tests: (1) an impact test—a 30-foot drop onto an unyielding surface; (2) a puncture test--a drop of 40 inches onto a six-inch in diameter vertical bar; (3) a fire test--30 minutes at 1,475° F; and (4) an immersion test—immersion in three feet of water for eight hours. Tests can be done with computer simulation, with scale models, or with the casks themselves.

The NRC is responsible for cask inspection before first use, but does not inspect the cask before each use. The DOT, through the Federal Highway Administration and the Federal Railroad Administration, inspects routes and rolling stock. There is no federal highway inspection program specifically designed for spent nuclear fuel shipments.[11]

In evaluating the cost and exposure of spent nuclear fuel transportation, the MRS Review Commission assumed that 54% of the fuel assemblies would be shipped by rail and 46% would be shipped by truck (only 54% of currently operating reactors have rail sidings). The Commission assumed, following the DOE, that dedicated trains would carry three casks from reactors to an MRS or repository and would carry five casks from the MRS to the repository (100% of shipments from the MRS to the repository would be by rail).[12] Under these assumptions, the RADTRAN model calculated the number of shipment-miles, cask-miles, and radiation exposure. The WACUM model calculated the cost of transportation.

A base case with the opening of a repository in 2013 without an MRS yielded 64.7 million shipment miles (MRS Report, p. 51). Because of the reduced number of casks with rail transport, a base case with an MRS opening in 2010 and a repository opening in 2013 yielded 26.9 million shipment miles (MRS Report, p. 53). Associated with this case was a total cost of 3.3 billion undiscounted 1989 dollars with 80% confidence that the transportation cost would be between $2.3 billion and $4.4 billion (MRS Report, p. 68). Total costs, with a 4% real discount rate, are $0.76 billion 1989 dollars. The Commission assumes all design and engineering

10. HMTUSA calls for the Secretary to "amend existing regulations as the Secretary deems appropriate to provide for the safe transportation by rail of high-level radioactive waste and spent nuclear fuel by various methods of rail transportation, including by dedicated train." See Section 15(b).

11. HMTUSA calls for regulations for vehicle inspection and certification, see Section 15(d).

12. The DOT's "Dedicated Train Study" will reexamine these assumptions.

costs are made in 1991 and no other transportation costs are made until the MRS opens in 2010. Implicitly, no improvements are made to the nation's roads, bridges, and railroads, contrary to Representative Udall in his opening statement in the *Nuclear Wast Transportation Hearings before the Subcommittee on Energy and the Environment* (U.S. Congress, House, Interior, 1988).

The assumption of no real increases in the cost of transportation probably understates future transportation expenses. The commission assumes a real discount rate of 4%. This is equivalent to the GAO nominal rate of 10% with a general rate of inflation of 6%. However, it is the rate of increase in the transport of hazardous materials that should be considered. If this rate is 10% nominal (i.e., a real discount rate of 0%), the discounted value increases to $3 billion (see figure 1). If the rate of increase is 15% (i.e., 9a real discount rate of -5%), the discounted value climbs to $30 billion. Positive real inflation can result from tighter regulatory stringency. For example, as the maximum allowable radiation dose for nuclear personnel decreases, training costs rise. See Rothwell (1991) on the role of regulatory stringency in forecasting reactor decommissioning costs.[13] On the other hand, technological advances and scale economies in transportation could decrease cost over time. More research is required.

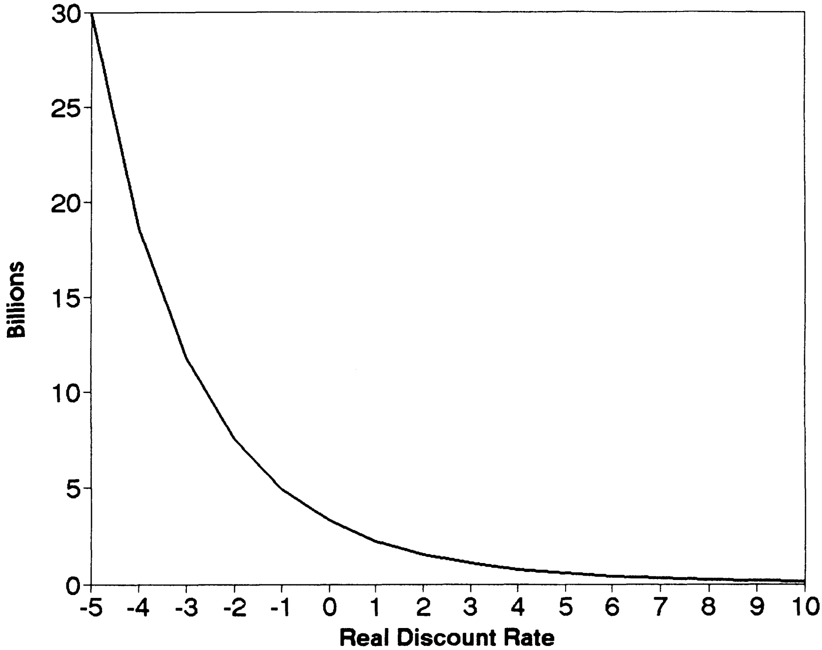

Figure 1: Transportation Expenses Discounted to 1989

13. Another source of this increase is litigation. See Wolfe (1992).

In addition to the monetary cost of spent nuclear fuel transportation and storage, the commission also calculated the human costs: radiological and nonradiological safety effects. Two types of radiological doses are (1) an "in-transit dose" that would be received by both the crew and the public during transport and (2) the "handling dose" to workers during loading and unloading casks from wet storage (or from dry storage back to wet storage) onto and from transportation vehicles. Because radiation exposure levels are lower for rail transport, the opening of an MRS facility, with the associated increase in rail use from the MRS to the repository, would lower the total transport dose from 12,200 rems to 9,000 rems. Again, a conversion rate of 1 cancer fatality to 2,500 rems yields between 3.6 to 4.9 extra cancer deaths for the entire life cycle of the spent nuclear fuel management system from 1990 to 2050.

This cost in human life is compared to the nonradiological effects of train and truck transport accident fatalities. The Commission assumed an aggregate rate of 0.05 deaths per million vehicle-miles for tractor-trailer trucks (according to a personal communication between the director of the DOT's Office of Motor Carrier Information Management and Analysis and a member of the MRS Review Commission staff, p. 58 of the MRS Report). Also, the commission relied on the DOT, Federal Railroad Administration's "Accident/Incident Bulletin No. 156" (July 1988, pp. 5, 16) for the rail fatality rate of three-to-five car dedicated trains:

> The fatality rate for entire trains is about two deaths per million miles. The rate for freight cars is much smaller. The freight-car rate is approximately 1/70 of the entire-train rate since trains average 70 freight cars each . . . This study uses the entire-train rate to estimate the fatality rate for these dedicated trains going to an MRS or repository, since the entire cargo is spent fuel. The collision of the train--not the number of cars involved--is the important component for calculating train accidents.

Under these assumptions the savings associated with fewer train shipments (i.e., through larger casks) are offset by an increase in traffic fatalities associated with rail, which might be overstated. Note, however, there have been no fatalities associated with spent nuclear fuel to date (see U.S. Congress, House, Interior, 1988, p. 357). The commission concludes that the nonradiological risks associated with the alternatives among the cases considered are small and that differences among them are insignificant in determining the need for an MRS (MRS Report, p. 53). Therefore, neither transportation mode is preferred.

Unfortunately, the commission's analysis uses aggregate traffic fatality statistics.[14] Their conclusions are not based on the accident probabilities associated with trucks weighing just under 80,000 pounds traveling interstate freeways or three- to five-car dedicated trains traveling designated track from specific reactor sites to specific storage (or disposal) sites. These probabilities could be higher or lower than those assumed; more detailed research is required. The lack of an MRS site hampered

14. These statistics can differ substantially for hazardous waste transportation. See Barkan (1991) and Hobeika and Harwood (1991).

the analysis of nonradiological accidents for truck and rail transport.

CONCLUSIONS

Although some engineering problems associated with spent nuclear fuel transport and disposal remain, notably in the design and manufacture of transportation and remote handling equipment, the primary problems are political and economic. The rise in states' rights and public intervention has stymied the siting of spent nuclear fuel storage and disposal facilities and the formation of transportation strategies. As these politics have been translated into regulatory stringency, cost uncertainty has risen. Nuclear electric utilities have been frustrated by both the executive and legislative branches of the federal government.

The MRS Review Commission was hamstrung by political compromise: to gain support for the siting of a long-term repository, concessions were made to legislators from states where shorter term storage had been proposed. The Commission was unable to consider specific sites for the MRS facility. Therefore, it was unable to calculate the probable costs, radiation exposure levels, or traffic accidents for specific routes from reactors. Because of the problems in disposal policy implementation, the Commission was given little time to do its job. Many of its unreasonable assumptions appear to have been made as a result of time pressure and not as attempts to steer away from politically unpopular findings. More analysis is required to adequately assess federal spent nuclear fuel interim storage. The Department of Transportation's studies (the "Dedicated Train Study" and the "Mode and Route Study") will address some of these same issues. In completing these studies, the DOT should:

1. Create models that consider technological alternatives with nonlinear tradeoffs between economics and safety, e.g., by allowing investments in transportation methods and equipment that reduce risk

2. Examine safety information for train and truck transport from operating reactors to specific storage sites

3. Give ranges (based on different rem-to-cancer rates) of extra cancers in spent nuclear fuel handling and transportation worker populations that can be expected for each transportation mode

4. Provide sensitivity analysis with respect to transportation inflation rates

More realism must be incorporated into the analysis of spent nuclear fuel transportation to provide a basis for more reasoned policy decisions.

REFERENCES

Barkan, C. P. L. 1991. "Quantitative Risk Assessment of Rail Transportation of Hazardous Materials." Presented at Hazmat Transport '91, The Transportation Center, Northwestern University.

Brown, N. K. 1985. "Monitored Retrievable Storage within the Context of the Nuclear Waste Policy Act of 1982."*Tennessee Law Review* 52, pp. 739-54.

Energy Information Administration. 1990. *Spent Nuclear Fuel Discharges from U.S. Reactors 1988.* March, SR/CNEAF/90-91.

Environmental Protection Agency. 1989. *Draft Environmental Impact Statement for Proposed National Emission Standards for Hazardous Air Pollutants for Radionuclides* . February, EPA 520/1-89-005.

Goffman, J.W. 1990. *Radiation-Induced Cancer from Low-Dose Exposure.* San Francisco, Committee for Nuclear Responsibility.

Hobeika, A. and D. W. Harwood. 1991. "Data Bases and Needs for Risk Assessment of Hazardous Material Shipments by Trucks." Presented at Hazmat Transport '91, The Transportation Center, Northwestern University.

Kassen, M. and C. Petti. 1988. "Testimony of the Environmental Defense Fund and Southwest Research and Information Center." In U.S. Congress, House, Interior (1988), pp. 183-224.

Monitored Retrievable Storage Review Commission. 1989. *Nuclear Waste: Is There a Need for Federal Interim Storage?* U.S. GPO# 022-003-01164-1, November 1.

National Academy of Sciences. 1989. *Report of the Committee on the Biological Effects of Ionizing Radiations --BEIR V.* December.

Office of Civilian Radioactive Waste Management (OCRWM), U.S. Department of Energy. 1987. *Characteristics of Spent Fuel, High-Level Waste, and Other Radioactive Wastes Which May Require Long-Term Isolation,* DOE/RW-0184.

Office of Technology Assessment (OTA), U.S. Congress. 1989. *Partnerships Under Pressure: Managing Commercial Low-Level Radioactive Waste,* OTA-O-426.

Pasqualetti, M. J. and Rothwell, G. S., editors. 1991. *Nuclear Decommissioning Economics.* A special issue of *The Energy Journal.*

ReVelle, C., J. Cohon, and D. Shobrys. 1991. "Simultaneous Siting and Routing in the Disposal of Hazardous Wastes." *Transportation Science* 25, 2 (May): 138-45.

Rothwell, G. S. 1991. "The Optimal Time to Decommission Commercial Nuclear Reactors," in Pasqualetti and Rothwell (1991).

U.S. Congress, House, Interior. 1988. *Nuclear Waste Transportation, Hearings before the Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs.* 100th Cong., 2nd session May 12.

U.S. Congress, House, Energy. 1985. *Transportation of Nuclear Waste, Hearings before the Subcommittee on Commerce, Transportation, and Tourism of the Committee on Energy and Commerce.* 99th Cong., 1st session August 1.

Wolfe, K. E. 1992. "Social Inflation: Assessment and Development of Measures to Account for the Impact of Increased Litigation on Transportation Accident Costs." *Journal of the Transportation Research Forum* 32:390-98

6

ANALYZING ROUTES FOR THE TRANSPORTATION OF HAZARDOUS MATERIALS INCLUDING RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL BY USE OF EFFECTIVE RISK ESTIMATION

Phillip Olekszyk

ABSTRACT

The Federal Railroad Administration (FRA) contributes to the routing of railroad movements through its regulatory program by assuring that all routes are safe for all commodities. The salient fact is that the safe transportation of hazardous materials by rail depends on the safety of the total rail system. That is, like all freight cars, those carrying hazardous materials must comply with federal equipment standards: they traverse track subject to federal track standards and signal system rules, both of which limit permissible speeds; they are subject to various operating rules; and the train crews must obey statutory hours-of-service limitations.

As a potential element in reducing the risks posed by rail transportation of hazardous materials, routing was previously examined by FRA and others. These include the General Accounting Office (GAO), the Department of Energy (DOE), ALK Associates, Inc., and Oak Ridge National Laboratory, all of which have studied various approaches to rail routing. These studies have identified a number of factors related to routing that can contribute to risk reduction, including track quality, population densities, elapsed time in transit and the length and directness of a route.

Currently, FRA's policy on spent nuclear fuel shipments is to inspect the entire rail route twice a year, operating practices annually and the equipment prior to each shipment.

RISK AND ROUTING

Rail transportation accidents involving hazardous materials, and the increase of radioactive wastes and spent nuclear fuel shipments, have intensified the public's awareness of these materials in recent years. Criticisms regarding population exposure, package design and routing through high-population localities have surfaced, advancing the need for risk estimation over various transportation routes.

The traditional approach to safeguarding the public from inherent risks attributed to hazardous materials releases is to specify design criteria and crashworthiness standards in packages. As an example, in three separate rulemakings, FRA required the installation of head protection (head shields), coupler vertical restraint systems (i.e., shelf couplers) and a thermal protection system (large capacity safety relief valves and thermal insulation) for certain high-risk commodities.[1] This approach is limited by the realization that engineering standards can only go so far in reducing accidents. Improvements in product containment may result from better handling and better routing choices based on risk estimation.

The Hazardous Materials Transportation Act (HMTA: Pub. L. 93-633) (49 App. U.S.C. 1801 et seq.) is the basic federal legislation which addresses the safe transportation of hazardous materials. Under the act, the Department of Transportation (DOT) has authority to regulate, among other things, the routing and handling of hazardous materials (see: 49 App. U.S.C. 1804). The department can exercise this authority in a number of ways. It can establish specific routing criteria, such as the avoidance of heavily populated localities or selection of routes least likely to result in the release of a hazardous material. The department can also establish procedural requirements for routing and handling of hazardous materials, such as a requirement that routing decisions be based on a documentable risk estimation methodology or a requirement that parties affected by the routing decisions be included in the decision making process.

DEDICATED TRAINS

To supplement the HMTA, the president signed into law the Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA: Pub. L. 101-615: November 16, 1990). HMTUSA amended section 116 of the HMTA to require the department to undertake a study comparing the safety of trains operating exclusively for transporting high-level radioactive waste and spent nuclear fuel (often referred to as "dedicated trains") with the safety of using other methods of rail transportation. The act also required the department to undertake a study to determine which factors, if any, should be taken into consideration by shippers and carriers in order to select routes and modes which, in combination, would enhance overall public safety related to the transportation of high-level radioactive waste and spent nuclear fuel. In assessing the degree of risk, the study must include various factors, including population densities, types and conditions of modal infrastructures, quantities of high-level radioactive waste and spent nuclear fuel, emergency response capabilities, exposure and other risk factors, terrain considerations, continuity of routes, available alternative routes and environmental impact factors that affect the overall public safety of such shipments.[2]

1. See Docket HM-144 (42 FR 46306) for new and existing DOT 112 and 114 tank car tank requirements; Docket HM-174 (46 FR 8005) for new DOT 105 tank car tank requirements and shelf couplers for new and existing DOT tank cars; and Docket HM-175 (49 FR 3468) for existing DOT 105 tank car tanks exceeding 18,500 gallons.

2. The department is not the only federal agency mandated by Congress to study radioactive waste and spent nuclear fuel routing alternatives. The Nuclear Waste Policy Act (Pub. Law 97-424) required the United States Department of Energy (DOE) to

The responsibility to conduct the dedicated train study lies with the FRA. Dedicated trains are characterized as special trains consisting of one or more locomotives coupled to a buffer car followed by the radioactive material cars, more buffer cars and a caboose. These trains generally travel at reduced speeds (35 to 55 mph) and usually stop for all passing trains. Special routing restrictions may also apply in which the railroad will attempt to avoid high population localities. The issue of dedicated versus regular freight train service has been an issue of great concern for several years. In fact, several cases have been litigated before the Interstate Commerce Commission (ICC).[3]

TRANSPORTATION OF LOW-LEVEL RADIOACTIVE WASTE

In addition to HMTA, section 8 of the Independent Safety Board Act Amendments of 1990 requires, among other things, that the secretary of transportation conduct a study of the transportation of low-level radioactive waste, including:

> an evaluation of the feasibility of requiring States that transport waste to a regional disposal facility established and operated under an Interstate Compact pursuant to Section 4 of the low-level Radioactive Waste Policy Act (42 U.S.C. 2021d) to use, to the maximum extent practicable, routes that are within the geographic borders of the states that are parties to the compact.

Under the Radioactive Waste Policy Act, Congress allowed states to formulate plans for the disposal of low-level radioactive waste generated within each compact's borders. Currently, nine compacts have been ratified by Congress and eight states remain unaffiliated. The compacts are approved by Congress. A state can exclude low-level radioactive waste material from another state that is not a party to the compact without violating the commerce clause of the Constitution.

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establish specific regulatory and procedural guidelines for spent nuclear fuel shipments. The DOE's Office of Civilian Radioactive Waste Management (OCRWM) was created under the NWPA to plan and establish specific regulatory and procedural guidelines for spent nuclear fuel shipments. The OCRWM has documented 111 commercial nuclear power plants in operation in the United States as of September 1992. Nineteen additional reactors are scheduled for completion in the near future. These facilities have produced nearly 20,000 metric tons of uranium (MTU) since 1984 and that figure will double by the year 2000. By the time the last license for the current generation of nuclear reactors expires, an estimated 84,000 metric tons of uranium will have been generated.

3. See Radioactive Materials, Missouri-Kansas-Texas R. Co., 357 ICC 458 (1977); Radioactive Materials, Special Train Service, Nationwide, 359 ICC 70, 74-76 (1978); Trainload Rates on Radioactive Materials, Eastern Railroads, 362 ICC 756, 773 (1980), aff'd and supplemented, 364 ICC 981, aff'd--sub nom. Consol. Rail Corp. v. ICC, 656 F.2d 642 (D.C.Cir. 1981) et seq.

It does not appear that this legislation will have a major impact on FRA or the involved railroads. The majority of low-level radioactive waste destined for disposal, under the compacts, is generally within a compact's boundaries (short movements compared to rail carriers) and often travels by highway. Since rail carriers maximize revenues by "long-hauling," a very low volume of traffic, if any, will be involved. According to the Association of American Railroads (TRAIN II data), there were only 226 shipments of low-specific activity radioactive material in the United States in 1989, a portion of which may include radioactive waste.

According to the *Congressional Record* (S17667, October 27, 1990), Congress believes that states should take full responsibility for the transportation of their own waste and use routes within a compact's borders; it is not right for a state to route its waste through another state simply to avoid a potential accident on its own roads. Congress asserts that states have an opportunity to shed responsibility for their own waste, either in disposal or transportation. Thus, the act requires the secretary to study the impact of requiring transportation routes within the geographic confines of the compact. Since the number of routing choices is comparably less for rail than highway, rail carriers may be at an economic, as well as competitive, disadvantage if routing requirements are imposed.

There are currently no published federal regulations pertaining to the rail routing of hazardous materials, including radioactive wastes and spent nuclear fuel. I say "published," because there are quasi-regulations that govern, among other things, the routing of hydrocyanic acid (HCN) and nitrogen tetroxide (N_2O_4). Both are poisonous by inhalation. Under DOT's regulations for those two commodities, shippers must file written safety procedures that specify routing/handling choices prior to offering the cars for transportation (see 49 CRF 173.332 and 173.336 for HCN and N_2O_4 respectively). Those routing choices include such information as:

1. The geographical rail route, including the nearest airport and county
2. Who to alert in case of an emergency
3. Instructions for on-scene-coordinators
4. Emergency response team instructions
5. First aid measures

The Department of Energy conducted two studies on the Three Mile Island rail route, one by Oak Ridge National Laboratory (Oak Ridge) and another by ALK Associates. Both Oak Ridge and ALK studied rail routing by using FRA's Rail Network model that was first developed in the 1970s. Oak Ridge's model predicts the shipping behavior of the railroad, that is, how the railroad is most likely to route a shipment in a given situation. The theory of the model is based on the assumption that railroads "maximize revenue" by taking a larger share of the route mileage (known as "long hauling"). ALK's routing model is similar to Oak Ridge's. The route identified has no constraints other than origin and destination, called "Minimum Impedance." ALK does, however, go one step further than Oak Ridge. It develops a risk estimation model by incorporating accident statistics and wayside population densities along a given route, in terms of nodes (cities, towns or junctions along a rail network) to define a route. The accident statistics are derived from FRA's Accident Incident Reporting System. The rail traffic data set is derived from the ICC Carload Waybill Sample and the population densities are based on county-level figures.

Oak Ridge used criteria obtained from DOE, which consisted of the following:

1. The quality of the railroad track
2. Avoidance of high population densities
3. The quickest, shortest and most direct route

Oak Ridge found that the quality of track was of primary importance in route selection. Currently, federal regulations require the rail carrier to classify its track by the degree of maintenance, as illustrated in the following chart (49 CFR 213.9):

Over track that meets all of the requirements prescribed for:	**The maximum allowable operating speed (in mph) for a freight train is -**	**The maximum allowable operating speed (in mph) for a passenger train is -**
Class 1........................	10	15
Class 2........................	25	30
Class 3........................	40	60
Class 4........................	60	80
Class 5........................	80	90
Class 6........................	110	110

Generally, the greater the quality of track and signaling systems, the greater degree of maintenance is required and the higher the speed a train can travel. Therefore, diverting shipments from high quality track (e.g. Class 6) to routes of lower quality track would increase the risk in transportation of spent nuclear fuel.[4] Paradoxically, selection of high quality track conflicts with the selection process, because high quality track traverses through high population localities. Unlike highway, rail shipments generally do not have bypasses around cities or other high

4. Nayak, Ranganath P., *Event Probabilities and Impact Zones for Hazardous Materials Accidents on Railroads*, (DOT/FRA/ORD-83-20) November 1981.

population areas, therefore railroads could be at the mercy of strict state and local regulations. The following chart lists five rail routes studied by Oak Ridge National Laboratory:

Rail Routes Evaluated by Oak Ridge

Route	Distance	Number of Interchanges	Population[a]
Primary	2,383	2[b]	1,179,583
Alternate 1	2,292	2	1,690,988
Alternate 2	2,322	2	1,591,208
Short Line	2,286	6[c]	1,591,126
"Hot Potato"	2,389	4[d]	783,338

Notes:

a. Number of people residing within 1 kilometer of the route
b. Interchange between the Missouri Pacific and the Union Pacific is not considered a full interchange
c. Includes a transfer with a terminal railroad
d. For more information, see footnote 3.

Oak Ridge concluded that the use of high-quality track, even through some highly populated localities, had a lower degree of risk than an alternate route with poorer quality track. These conclusions were previously drawn by Glickman. Glickman estimated from historical statistics that the expected number of casualties (deaths and injuries requiring medical attention) in 1977 would have increased 20% if shipments were rerouted. The study indicated that the advantages of reducing public exposure to hazardous materials shipments were outweighed by the disadvantages of forcing traffic onto poorer track.[5]

In addition to the Oak Ridge study, in a report entitled *Review of the Selection of the Rail Route for Shipping Three Mile Island Debris* (November 1989), DOT's Transportation Systems Center (TSC) reconstructed the process by which DOE chose the current route. TSC reviewed all correspondence, directives and reports made available by DOE and the routing models (such as the nature of inputs, outputs, assumptions, data and algorithms). TSC found the route to be a reasonable choice when evaluated against the multiple objective route selection criteria.

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5. Glickman, Theodore S., *Analysis of a National Policy for Routing Hazardous Materials on Railroads.* United States Department of Transportation. Draft Report, 1980.

FRA INSPECTIONS OF HIGH-LEVEL RADIOACTIVE WASTE

Currently, FRA's policy on spent nuclear fuel shipments is to inspect the entire rail route (track and signalling systems) twice a year, operating practices annually and the equipment prior to each shipment. Our inspection commitment regarding hazardous material shipments that are of great public concern is a good indicator of our interest in safety and the quality of the rail route.

Since the first high-level radioactive waste shipment in 1986, FRA has inspected each high-level radioactive material train at the point of origin and at all interchange points.[6] Each train is inspected several times. First it is inspected by the carrier. FRA Hazardous Material and Motive Power and Equipment Inspectors then ensure compliance with the Hazardous Materials Regulations (e.g., documentation, train placement, crew notification and placarding requirements) and the Freight Car and Safety Appliance standards for locomotives, cabooses, and buffer and cask cars. Like the majority of hazardous material shipments, these high-level nuclear waste shipments arrived safely at destination.

Other modal routing requirements of great interest to FRA were promulgated by DOT for the transportation of radioactive materials by highway on January 19, 1981 (HM-164: 46 FR 5298). The purpose of the rulemaking was "to protect the Nation adequately against the risks to life and property which are inherent in the transportation of hazardous materials in commerce" (49 U.S.C. 1802) and "to preclude a multiplicity of state and local regulations and potential for varying as well as conflicting regulations in the area of hazardous materials transportation" (Senate Report 1192, 93rd Congress, 2d session, 37 [1974]). Prior to the issuance of this rulemaking, several states and local governments passed legislation severely restricting the transportation of hazardous materials, including spent nuclear fuel. This multiplicity of state laws provided an undue burden on interstate commerce, which increased the risks of transporting these materials. Hence, the Research and Special Programs Administration (RSPA) could exercise statutory preemption under the new rule. In addition, while a federal court may find that a requirement is not statutorily preempted, it could nonetheless be preempted under the commerce clause of the U.S. Constitution (48 FR 761).

The final rule requires highway carriers of highway route-controlled quantities of radioactive materials (which includes spent nuclear fuel) to use preferred highway routes, which are selected to reduce the time in transit. Preferred routes consist of interstate highways with the use of interstate bypasses around cities when available and alternate routes selected by a "State Routing Agency" (49 CFR 177.825). Much of the risk estimation criteria (i.e., quality of the highway and population exposure) in the final rule is analogous to the FRA and DOE studies.

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6. Among the routes inspected: Three Mile Island, Pennsylvania, to Scoville, Idaho; Cooper Station, Nebraska, to Morris, Illinois; Monticello, Minnesota, to Morris, Illinois; Robinson, South Carolina, to Bonsal, North Carolina; and Wilmington, North Carolina, to Bonsal, North Carolina.

In addition to the routing requirements for highway route-controlled quantities of radioactive materials DOT also issued an Advanced Notice of Proposed Rulemaking on routing standards for nonradioactive hazardous materials (HM-203 [53 FR 11618]). As with the HM-164 rulemaking, FRA is considerably interested in the outcome of this rulemaking, especially the criteria in evaluating risks over transportation routes.

7

WORKING TOGETHER TO BUILD A SAFER FUTURE

Mark Abkowitz

ABSTRACT

Ensuring the safe transport of hazardous materials (including substances and wastes) is a matter of growing concern among public citizens, government regulators, and shippers and carriers. Improvements in operational safety are made difficult by the technical and social issues which must be collectively resolved if measurable progress is to be made. Many of these issues can be broadly grouped into considerations related to routing, evaluating and communicating risk, emergency preparedness, data collection and information management, and inspection and enforcement.

The purpose of this paper is to explore the current environment in which hazardous materials transport safety is being addressed, progress made to date in the safety of such transport, and the potential for future improvements. It is argued that a constructive and good faith relationship between industry, government, public interests and other constituencies is the foundation for future progress. The paper includes a discussion of strategic initiatives for fostering improved safety while sustaining the economic viability of transporting dangerous goods.

INTRODUCTION

The transportation of hazardous materials is inherent in any advanced and technologically complex society. A number of industrial processes of vital economic importance are dependent on the uninterrupted flow of hazardous materials shipments. Within the United States, this level of activity generates over 1.5 billion tons of hazardous materials transported annually by highway, railroad, waterway and air [1].

While the vast majority of these shipments occur without incident, a single shipment can pose the potential for significant health consequences to the population and irreparable harm to the environment in the event of a release. For this reason, ensuring the safe transport of hazardous materials is a matter of growing concern among citizens, government regulators, shippers and carriers. This concern has prompted a considerable amount of recent activity directed at government oversight and operating practices in an effort to establish adequate safety performance within the transport industry.

Improvements in operational safety are made difficult by the technical and social issues which must be collectively resolved if measurable progress is to be made. Although these issues are numerous and can be classified according to a variety of definitions, much of the recent attention has focused on the following subjects [2]:

- Routing considerations
- Evaluating and communicating risk
- Emergency preparedness
- Data collection and information management
- Inspection and enforcement

Within these areas exist other contentious issues related to jurisdictional authority, liability, equity and alternative hazard communication systems.

INTEREST GROUPS AND THE PERSPECTIVES

There are several distinct interest groups which have a stake in the reduction of hazardous materials transport risk, both to the population and to the environment [3].

The Public

The public is becoming much more aware of and concerned with the potential dangers involved in hazardous materials transportation. This heightened awareness and subsequent pressure exerted on the political process has paved the way for the introduction of regulatory policies aimed at reducing the risk of hazardous shipments. Previous regulatory policy had tended to focus on specific materials and/or types of shipments, such as the movement of radioactive wastes. However, with the passage of the Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA), this attention is now being extended to a major segment of the industry.

Government

Government agencies run by elected and appointed officials, although created to implement public will, have a broad responsibility that encompasses issues related to both public safety and economic vitality. Consequently, the role of government often becomes one of brokering public sentiment and operational practice by setting policies designed to achieve some type of acceptable compromise.

Industry

Finally, there is industry. Providing the goods and services demanded by the public creates potential conflicts where economics and safety can present competing objectives. Recent evidence, however, suggests that a reduction in the adverse effects of commercial transportation on the community has also become a primary shipper and carrier concern. The Chemical Manufacturers Association (CMA) has implemented, under the Responsible Care program, a number of initiatives directed at formalizing the risk management function and identifying risk reduction strategies. Individual shippers are sponsoring the development of methods and systems that can be used to assist decision makers in addressing transport safety considerations. The Hazardous Materials Advisory Council (HMAC) is taking a leadership role in providing educational training to industry managers and staff on regulations related to packaging, materials handling and other pertinent operational elements.

Some may wish to question why industry is becoming so proactive. There are, however, several motivating factors. First, there is a strong campaign within industry to promote itself as a good corporate citizen, concerned about its place within the community and the nation. Second, there is the ever-present legal system which, at least in practice, places liability for adverse consequences resulting from incidents proportionally to the depth of the financial resources of the named defendants. Finally, even if legal liability cannot be attributed to a specific company, the public is likely to consider that firm to be at least partially accountable for the consequences of an incident, thereby tarnishing its public image.

Although perhaps ironic, it is apparent that the various interest groups are essentially seeking the same goal. While this unified vision is brought about by explicit self-interest on the part of each group, its mere existence provides a tremendous opportunity for effecting sensible improvements in the overall safety of hazardous materials transport operations.

In the following discussion, this opportunity is explored for several significant areas involving hazardous materials transport policy. In doing so, it is important to note that while there may be concurrence among various interest groups on the intent of certain policy initiatives, there may be disagreement on how such policies should be implemented because of the multiple perspectives involved.

ROUTING

If there was a time when the routing of hazardous materials was not a contentious issue, that time has passed. In recent years, the U.S. Department of Transportation (DOT) has been brought more frequently into resolving disputes over the designation of restricted routes for hazardous materials shipments in various locations around the country. What used to be a set of suggested criteria for designating preferred routes has evolved into a directive within HMTUSA for DOT to set standards governing route selection, leaving the states with responsibilities for implementing and enforcing the use of designated routes. The states of California and Colorado have, of their own volition, instituted statewide networks of designated routes for certain dangerous goods movements.

There are several problematic issues that characterize the routing problem. One is that, while the general public may have little objection to the use of hazardous materials in industrial processes to support consumer needs, nobody wants to have these shipments traveling through their communities in vast numbers. This "Not In My BackYard" (NIMBY) syndrome is certainly well understood.

The intent of designating preferred routes is to find the safest path(s) linking shipping origins and destinations in the United States. Once these paths are selected and presumably enforced, this would shift hazardous materials traffic onto a few routes carrying significantly greater volumes of dangerous goods. The net result would be many communities ridding themselves of the NIMBY problem at the expense of a few "losers"—communities that end up bearing the burden of a disproportionate risk for the betterment of mankind. Whether this is fair and how to contend with this issue has spawned the notion of risk equity, an identified problem without a practical solution as yet.

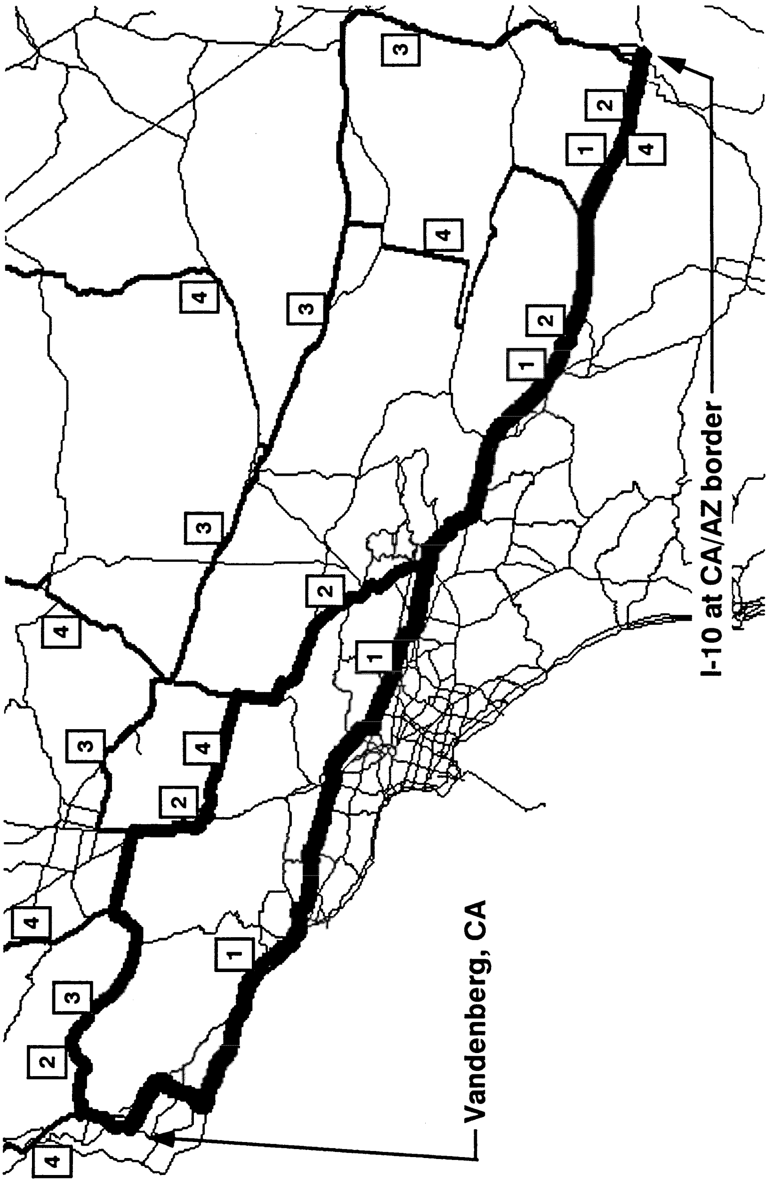
Routing problems for shippers and carriers come in multiple forms. One is cost. Virtually any routing designation that takes into consideration risk reduction will likely divert hazardous shipments away from heavily populated areas. Since our nation's transport systems were originally designed and constructed to serve and connect concentrated populations, designated routes are likely to create more circuitous routings. Use of those routes will be more time-consuming and therefore transport costs will increase. Such increases may not be easily tolerated by carriers in what is currently an extremely competitive industry with narrow profit margins.

Perhaps an even more perplexing problem is the potential web of confusion under which interstate shipments might be transported if each individual state is left to its own devices in implementing federal routing guidelines. Without the close coordination between neighboring states needed to establish an integrated network, it could become extremely difficult to successfully complete an interstate movement. Furthermore, it could be argued that some states might desire to purposely achieve this result to discourage through traffic from using their transport facilities, in effect diverting unwanted traffic to a neighboring state.

The most difficult problem, however, may rest with the states themselves. Even by acting responsibly, the selection of routing criteria and criteria weightings will have a profound effect on the routes ultimately selected for inclusion in a designated network. This is aptly illustrated in an analysis that the author performed in southern California. It was conducted using a software tool designed to select preferred routes for shipping and receiving points located in the continental United States based on designating which HMTUSA routing criteria should be considered and the associated weight (importance) placed on each specified criterion.

Figure 1 displays a map of four different preferred routes for a shipment of chlorine from the I-10 Arizona/California border crossing to Vandenburg, CA, found

Figure 1.
I-10 at Arizona Border to Vandenberg Routing Application



by varying criteria selection and weighting. Route 1 represents the route which minimizes travel time. Route 2 was established by applying routing criteria with a 75% weight on travel time minimization and a 25% weight on risk minimization. Route 3 represents an application of criteria with a 25% weight on travel time minimization and a 75% weight on risk minimization. Route 4 is based exclusively on risk mini-mization.

Several observations are apparent when reviewing these results. First, the application of different criteria and criteria weights does result in the selection of different preferred routes. Although this result may be obvious, the results demonstrate that when risk criteria are applied, alternate routes would be selected that differ from those currently used by industry.

Another important and related finding is that if designated routes are based solely on risk minimization, they result in selection of routes which are so circuitous that they would appear to be economically infeasible. As noted in table 1, route 4 more than doubles the travel time when compared to the minimum travel time route (route 1). This result suggests that any reasonable system of designated routes must seek a compromise solution that introduces improved safety without making the trip extremely cumbersome. The important implication of this finding is that routing regulations should not be based exclusively on finding the least risk route. This implies that states will need to address the question of "How safe is safe enough?," leading to a goal of achieving practical (as opposed to optimal) safety.

Fortunately, this case also illustrates that the problem may be reconcilable by finding advantageous tradeoffs between travel time and risk achieved by adjusting criteria weights. As can be seen in table 1, route 2 (75% travel time minimization, 25% risk minimization) identifies a route which, when compared to route 1, introduces only a 3% increase in travel time while reducing risk by 70%. This tradeoff would improve public safety considerably with a negligible effect on carrier efficiency. Similarly, route 3 introduces an 8% increase in travel time while reducing risk by 82%.

EVALUATING AND COMMUNICATING RISK

Risk evaluation, a necessary process for making rational decisions on how to move hazardous materials safely, generally involves conducting a risk assessment. Risk assessment is performed in order to understand the likelihood of a potential incident involving a particular commodity movement, and its related consequences in terms of threat to public health and damage to the environment. This process can also be repeated across a number of alternatives (e.g., different modes, routes, incident locations, commodities, shipment volumes, packagings, etc.) in order to rank these alternatives for the purpose of identifying the best option when all issues are considered. In that regard, there is no question that routing decisions are the most frequent use of transportation risk assessment.

The concept of risk assessment and its integration into management decision making is becoming a more accepted practice by both industry and government. Both

Table 1. Case 1 Route Analysis Impacts

Route	Distance	Travel Time	Population	Accident Likelihood	Risk
1	388.88	7h 55m	3,059,409	0.000306	17.84
2	435.29 +12%	8h 11m +3%	819,688 -73%	0.000376 +23%	5.44 -70%
3	493.14 +27%	8h 32m +8%	214,961 -93%	0.000433 +42%	3.17 -82%
4	973.83 +150%	19h 27m +146%	311,859 -89%	0.000613 +100%	0.92 -95%

the states of California and Colorado have utilized risk assessment as a significant part of the routing methodology used to designate an intrastate routing network. Through the CMA, a Distribution Code of Risk Management Practice is being adopted by all member companies, ostensibly requiring each company to implement a risk management program and to integrate risk assessment into the safety management process. Other efforts, such as the Inter-Industry Rail Safety Task Force, are also notable in this regard.

With a critical mass of risk assessment believers now becoming established, emphasis has shifted to: (1) the availability and quality of data to support risk assessment on local, regional and national bases, (2) achieving agreement on acceptable definitions of risk and risk measurement, (3) developing and standardizing the tools available for performing risk assessment as a stand-alone analytical tool that can be used in conjunction with routing and emergency management decisions, and (4) distinguishing between use of risk assessment for screening methods versus comprehensive analysis.

Understanding risk as a technical issue and communicating it as a social issue are two entirely different considerations. Risk communication is a formidable challenge, due in part to a basic mistrust of big business and government that has formed in the public mind over the past few decades. The budding area of risk communication must, therefore, mature not only as a science but also as a process. The process involves building confidence and credibility by being forthright and getting the community involved in the early stages of the planning effort.

A principal issue within risk communication is the public perception of risks that involve health safety, such as those posed by hazardous materials transport. There is a tendency for the public to assume a risk averse posture when evaluating the risks of alternatives (e.g., route designation). A risk averse posture is based on a perception that one incident that kills 100 people is more onerous than 100 accidents, each of which causes a single fatality. This contention is supported by public reaction to the very few airline accidents each year that result in numerous fatalities per accident in contrast to traffic accidents, which cause few fatalities per accident but result in nearly 50,000 annual fatalities on our nation's roadways.

Risk aversion (or perceived risk in this instance) can be represented in a technical risk assessment by applying an exponent to the consequence term in the risk expression. If the exponent is set equal to a value greater than one, consequences are magnified beyond their expected impact. More serious consequences generate a larger relative increase in expected impact when the exponential term is applied. This, in effect, creates the desired risk averse condition.

Is this a significant problem? Returning to our California study area, a routing analysis was performed for a chlorine shipment from Capistrano to Thousand Oaks. In one case, the preferred route was selected on the basis of minimizing actual risk, while in the other case the criterion was to select the route which minimizes perceived risk. The preferred routes are displayed in figure 2. As can be seen, the identified routes deviate from one another north of downtown Los Angeles. The important point here is to recognize that, based on perceived risk, the public would likely choose a different route than the one that would be identified using actual risk measures. In

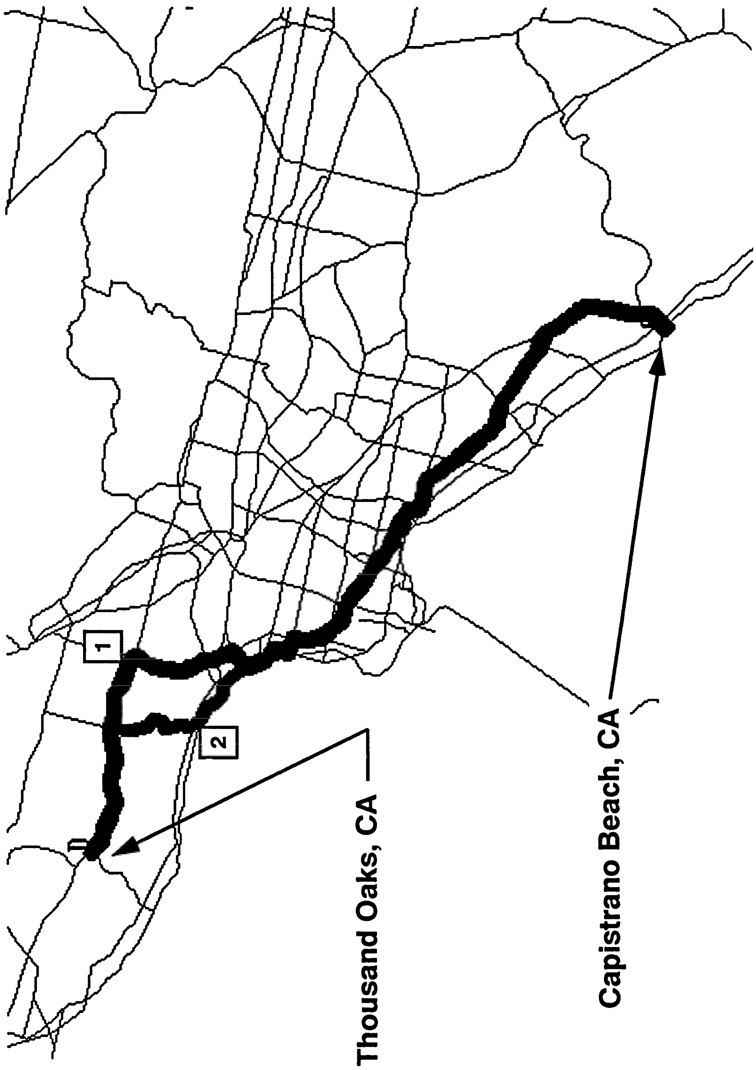


Figure 2.
Capistrano Beach, CA to Thousand Oaks, CA Routing Application

general, the difference leads to a perplexing question as to which risk measure is more appropriate since routing is inherently a public policy consideration.

At a minimum, the problem suggests that if regulators use technical risk in their route designation studies, attention must be devoted to the identification of preferred perceived routes, with attempts made to educate the public to understand the bias in their perception. Ideally, risk communication will one day improve to where there is no discernable difference between actual risk as we measure it and how it is perceived by the public.

EMERGENCY PREPAREDNESS

In reviewing the current status of hazardous materials transport emergency preparedness in the U.S., there is more agreement on the work needed to improve emergency preparedness than there is on the degree to which we are adequately prepared at the present time.

Fortunately, a number of significant actions have been (or will soon be) taken to help resolve some of the major roadblocks to overall emergency preparedness capability. They include the following:

- The Superfund Amendments Reauthorization Act (SARA) Title III has been enacted and is being implemented by a number of states and localities

- Greater efforts are being made by the Federal Emergency Management Agency (FEMA) to focus on preparing communities for all types of emergencies

- An administrative arrangement for achieving cooperation between five federal agencies has been established, with FEMA's role strengthened and clarified

- National competency standards for responders have been prepared

- DOT is spending more time on hazardous materials transportation management issues than ever before

Added to this list are the provisions established in HMTUSA to provide an expansion in federal funding for emergency response planning and training through a user fee structure, beginning in FY 1993.

With increased awareness of the need to improve hazardous materials transport emergency preparedness has come greater agreement among the parties involved as to what constitutes adequate emergency preparedness. Encouraging examples of coordinated planning and response have been reported through the Transportation Community Awareness and Emergency Response (TRANSCAER) program, developed by the CMA. The key ingredient appears to be that industry work closely with local officials and then succeed in having localities make their own planning and response mechanisms. CMA is also preparing stringent disposal codes under its Responsible Care program, and the American Petroleum Institute (API) has adopted a set of operating procedures.

Successful response programs are characterized by cooperation and communication. To have adequate cooperation and communication, however, the people involved must acquire information; it does not come to them without effort. The kind and quality of the information that is needed has progressed beyond the basics. There is growing knowledge as to the resources and systems needed to respond to an incident, including:

1. Development of a good plan
2. Ultimate authority in one place during an incident
3. Proper basic equipment
4. Proper technical communication equipment
5. Quick access to experts, but final control over their differing views
6. Ability to use media effectively to help
7. Basic level of knowledge at dispatch, police, firefighter and local elected official levels
8. A satisfactory decision-making process
9. Knowledge of what to look for and how to identify products

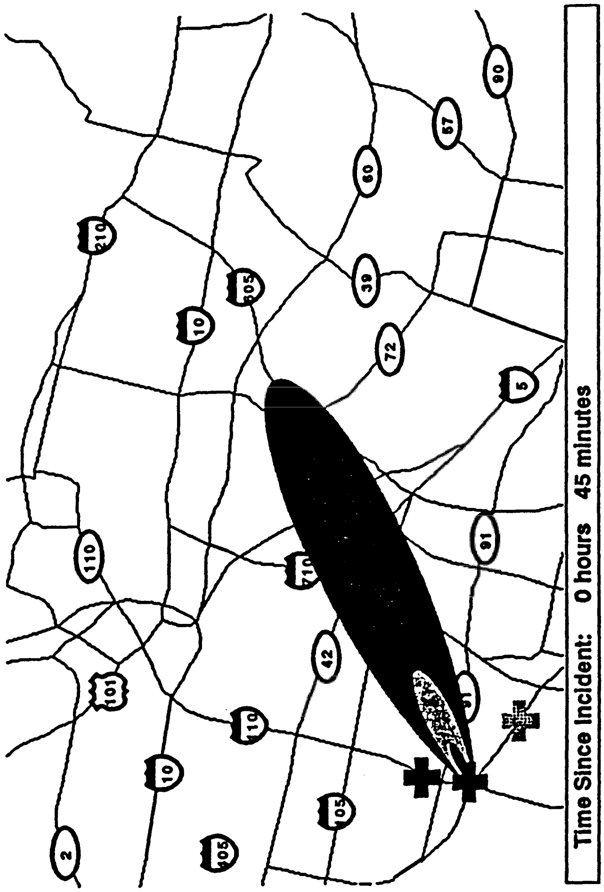
Despite these encouraging signs, adequate preparedness on a national basis is still a long way off, primarily because many of those involved in this effort are volunteers. Volunteerism, for all its merits, presents problems, particularly in a discipline such as hazardous materials emergency preparedness, where advanced communication, information-gathering, and response capabilities are needed to ensure public health and environmental safety.

This situation may be one of the reasons why industry has been lobbying for the institution of regional response teams. Staffed with highly trained professionals, these teams would serve as the ultimate responders for most incidents. Should this come to pass, however, it will not alleviate the need for close coordination and cooperation with local responders, typically firefighters. Local responders will generally arrive first on the scene and will be required to make real-time decisions in terms of evaluating traffic, re-routing, etc. This situation is illustrated in figure 3, where the first responders are identified by a darkened cross and the ultimate responder, yet to arrive on the scene, is represented by a lightly shaded cross.

DATA COLLECTION AND INFORMATION MANAGEMENT

To support planning and emergency management applications directed at risk reduction, it is imperative that data used in conjunction with these efforts are available and credible. Three primary areas of information retrieval involve incidents, commodity movements, and hazard identification.

Figure 3.
Emergency Response Deployment to an Incident Location



The quality of incident databases has been investigated by several researchers in the past decade [5]. Their studies have raised several serious questions, including these two: (1) Are all relevant hazardous materials transport incidents being counted? and (2) How valid is the information contained in the incident reports that have been filed? The magnitude of this problem varies at different geographical levels, and is most acute at the federal level. A major national effort should be directed at improving the quality and compliance of incident reporting.

Commodity flow information is also a critical element in the safety equation because it provides a measure of exposure from which to normalize incident frequencies. Under HMTUSA, commodity flow data will be taking on even greater significance as an integral part of emergency response planning. It has been acknowledged that whereas reasonably reliable information exists from which rail and waterway commodity flows can be estimated, there is no companion information system to track hazardous commodity movements by truck. The mode that carries the largest number of hazardous materials shipments and tonnage, and the one that travels through the most communities, is the mode with the least amount of available flow information. Clearly, the development of a primary truck movement information system is a priority [6].

The final major information management issue brought forward by HMTUSA is the role of alternative hazard communication systems. Originally introduced as legislation by Congressman Applegate and currently under legislated study by the National Academy of Sciences, considerable controversy has been generated by this initiative, largely because the issues are not well understood.

The thesis behind the original proposed legislation is that an alternative hazard communication system is necessary because the current placard system is failing. It is alleged that when an incident occurs, emergency response personnel arriving on the scene might find an unplacarded or misplacarded container, necessitating examination of the shipping manifest in the vehicle to ascertain the true nature of the cargo. In doing so, the responder might discover that he/she has already become exposed to a harmful dose of the material.

The proposed alternative system would use electronic communications, require every hazardous materials shipment to be catalogued, and require industry to bear the full cost of implementation. Industry balked at the tremendous cost involved both in terms of filing fees and staff time to log required information, and questioned whether such a comprehensive system was necessary or cost-effective. Fortunately, an objective third party has been given the opportunity to explore these questions at the level of detail that is justified.

It is the author's premise that this study should be segmented into sequential steps designed to answer the following questions: (1) Is better product identification necessary? and (2) If so, what is the benefit/cost of alternative hazard communication systems? The first question focuses on whether the existing placard system is adequate as a hazard communication system provided that compliance could be assured. If the answer to this question is "yes," then the issue really becomes one of improving enforcement.

If it is concluded that the placard system is inadequate or cannot, in and of itself, be trusted for ultrahazardous shipments, alternative communication systems warrant serious consideration. The key to evaluating these alternative systems must still remain the level of system reliability that can be achieved. For example, if a delinquent shipper/carrier improperly placards a container or purposely misreports or omits information on the manifest, one might expect the shipper/carrier to behave similarly under an automated information reporting system. Consequently, if an incident occurred involving such a shipment, there is no assurance that an automated system would contain a recorded entry for that shipment or could supply accurate information on it.

There are a multitude of other factors warranting consideration in such a study as well. They include: (1) ability to cross-reference the vehicle and the shipment, (2) information retrieved in a timely fashion, (3) tracking intermediate points where loading/unloading operations can affect the contents of a shipment, (4) system security, (5) processing of up to 500,000 entries per day, and (6) a variety of other human factors considerations. The answer to the problem of accurate information and its effective communication may well be that safety benefits drive the system sufficiently to assure adequate implementation for a subset of hazardous materials shipments that pose such a significant threat to public health and the environment that identification beyond placarding is justified.

INSPECTION AND ENFORCEMENT

As greater emphasis is placed on ensuring that existing safety regulations are being followed, the role of inspection and enforcement has become expanded and better defined. This activity currently includes oversight on vehicle and terminal operations, and a variety of reporting requirements (e.g., manifests, incidents, etc.), involving both federal and state inspectors. HMTUSA contains provisions to increase the number of federal inspectors on all transportation modes to enforce the regulations. Similar assistance has been provided directly to the states in recent years through the Cooperative Hazardous Material Enforcement Development Program (COHMED) and the Motor Carriers Safety Assistance Program (MCSAP). Some states have also increased their enforcement efforts by instituting their own fee systems.

Given this infusion of support for inspection and enforcement, the focus is shifting towards concern for implementing cost-effective programs. Key issues in this regard appear to be (1) cooperation, (2) communication, and (3) training.

Cooperation is needed to ensure that there are active, ongoing positive relationships between the state and local emergency planning communities and groups that enforce the hazardous materials transportation regulations. Although the relationship between these two groups have improved in some jurisdictions because of the requirements of Title III of SARA, there are substantial opportunities to continue to improve cooperation in many jurisdictions. One way to promote cooperation is to name representatives of the enforcement community to the state emergency response commissions and local emergency planning committees.

Improved communications and information-sharing would also aid in the coordination process. For example, emergency response plans developed by various state and local government entities need to pay more attention to the enforcement component of emergency situations.

Training is now being identified as the key missing ingredient in the overall effectiveness of inspection and enforcement. There is no question that training and the effectiveness of many hazardous materials inspection/enforcement officers has been enhanced significantly as a direct result of MCSAP and associated information dissemination efforts of DOT. Similarly, HMAC has been instrumental in educating shippers and carriers about current regulations that affect operating practices.

It is important to recognize that even with the large strides that have been made recently in improving the inspection and enforcement function, the desired effect cannot be achieved without greater industry compliance. In the past, even when violating firms were caught and prosecuted, resulting fines were so low that many shippers/carriers treated such occurrences merely as an occasional "cost of doing business." Political support has been lacking in the past for promoting compliance with the hazardous materials transportation regulations. HMTUSA increases civil and criminal penalties for these violations. When coupled with an expanded and more competent enforcement function, this could lead to a substantial improvement in rates of compliance.

STRATEGIC PLANNING FOR A SAFER FUTURE

Because of the opportunity created by various interest groups that exhibit a unified commitment to improved hazardous materials transport safety, a strategic action agenda can be established to ensure a safer future. Due to progress made to date, the platform for this agenda can be structured around proactive rather than reactive judgment.

The time has come for the issue of routing to be tackled head-on. Criteria and criteria weighting must be defined for designating routes that take into account both reduced risk and carrier efficiency. Government and industry must work together towards route designations that stress practical improvements in safety. It has already been demonstrated that reasonable solutions often exist that generate most of the risk reduction benefit without imposing excessive reductions in carrier efficiency.

States must work together, facilitated by DOT, to achieve a balanced interstate network of designated routes so as to provide industry with reasonable through and access opportunities. The concept of risk equity should be factored into this process.

Communicating safety policy to the public, whether it be routing, emergency preparedness or other issues involving hazard assessment and mitigation, must receive greater attention. The public is a significant player in the process and, given its inherent bias towards risk aversion, a systematic process must be adopted, by both government and industry for educating the public and involving it in the early stages of projects.

Likewise, emergency preparedness is becoming a high-profile issue in terms of the need for better interagency cooperation, communication and training. Improved emergency response planning and increased training should be given priority attention, but in a structured fashion, from the infusion of new resources. Coordination between industry regional response teams and local first responders is also an important linkage that should be facilitated.

One of the key elements in supporting this process of establishing a strategic action agenda is the availability of credible data. A major national effort must be directed at improving the quality of and compliance with incident reporting. Similarly, the development of a truck commodity flow information system is desperately needed to support hazard assessment and emergency response planning.

The need for an alternative hazard communication system should be given careful consideration. The reliability of the current placard system or one which might supplement or replace it must be such that cargo information is available, timely and accurate. A proactive approach and cooperation by government and industry on this issue could transcend the political aspects involved, again leading to a solution that provides practical improvement in transport safety.

Additional resources have become available to support inspection and enforcement. Therefore, there will be a greater need for interagency cooperation. Cooperation is needed not only to coordinate efforts, but also to direct those efforts towards greater industry compliance. Improved enforcement coupled with higher penalties may prove to be the proper combination that has been lacking in the past.

In developing strategic initiatives that respond to these considerations, it is important to recognize that many of the issues that have been described individually in this paper are highly integrated and must be so addressed. For example, routing decisions should not ultimately be made without evaluating response coverage on route segments under consideration. Therefore, a top-down approach to a strategic action agenda is recommended, with careful consideration given to understanding how these issues are connected.

The essential ingredient to future success, however, will remain the delicate partnership which is forming between the federal government, state and local governments, and industry in addressing hazardous materials transport safety. Without a commitment from all parties, the aforementioned opportunities will become merely rhetoric as so often happens regarding sensitive public policy issues.

REFERENCES

[1] U.S. Congress, Office of Technology Assessment. 1986. *Transportation of Hazardous Materials*. OTA-SET-304; Washington, D.C.: U.S. Government Printing Office, July.

[2] Abkowitz, M. et. al. Forthcoming. "State and Local Issues in Transportation of Hazardous Materials: Towards a National Strategy." *Transportation Research Record.*

[3] Lepofsky, M., M. Abkowitz and P. Cheng. 1991. "GIS-T for Environmental Hazards Analysis and Incident Management." Presented at the Geographic Information Systems for Transportation Symposium, Orlando, Fla., March.

[4] Abkowitz, M., G. List and A. E. Radwan. 1989. "Critical Issues in Safe Transport of Hazardous Materials." *Journal of Transportation Engineering* 115, no. 6:608-29.

[5] Abkowitz, M. and G. List. "Hazardous Materials Transportation Incident/Accident Information Systems." *Transportation Research Record* 1148 (1987): 1-8.

[6] List, G. and M. Abkowitz. "Towards Improved Hazardous Materials Flow Databases." *Journal of Hazardous Materials* 17 (1988): 287-304.

8

MULTIOBJECTIVE POLICY ANALYSIS OF HAZARDOUS MATERIALS ROUTING

Mark A. Turnquist and George F. List

ABSTRACT

This paper is a case study in developing policy options for regulating hazardous materials truck transportation routes. The case study setting is the Capital District of New York State, and the analysis is directed at hazardous waste shipments entering the area and bound for a treatment site within the area. The analysis is based on using a multiobjective routing model to provide a set of nondominated routing alternatives, from which various policy options are developed. The conclusions are that such analysis is feasible and tractable, and that policies based on a few selected link restrictions can provide substantial public risk reduction without excessive micromanagement of carriers.

INTRODUCTION

The Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA) quotes U.S. Department of Transportation (DOT) estimates that more than 500,000 shipments of hazardous materials move daily through the U.S. transportation system, and the total volume of movement approximates 4 billion tons per year. Although the accident rate on these shipments is very small, the large number of shipments makes it a virtual certainty that accidents will occur, and there is increasing public sensitivity to risks associated with hazardous material shipments. From a public perspective, the level of risk can be managed by either restricting or designating routes for these shipments, and it is this aspect of hazardous materials transportation on which we focus in this paper. HMTUSA devotes considerable attention to the issue of route restrictions and designations, and specifies several factors which must be considered by states in making such policy decisions.

In analyzing routing options for hazardous materials shipments, it is important to recognize that there are multiple interested parties, or stakeholders. These stakeholders include shippers, carriers, local fire departments, state departments of transportation and/or environmental protection, federal agencies, and citizen groups, among others. Each of these interesed parties may bring a different set of values and/or criteria to bear in assessing any particular solution. Thus, we must incorporate multiple objectives in our analysis and decision making. For example, the recent federal legislation mentions the following factors explicitly:

1. Population density
2. Type of highway
3. Types and quantities of hazardous materials
4. Emergency response capabilities
5. Exposure and other risk factors
6. Delays in transportation

The existence of multiple criteria means that it is not usually possible to identify a single "best" route between a given origin and destination. For example, one route may minimize the number of people at risk while a second minimizes the probability of an accident, and a third minimizes delays. In this context, attention should be focused on finding a set of "nondominated" routes which represents the available tradeoffs explicitly. (One route dominates another if there is at least one measure, or criterion, on which it is preferred, and there is no measure on which the other route is preferred.)

The research reported in this paper illustrates the use of a multiobjective routing model for developing policy options on route restrictions/designations in a regional area. As a case study, we have chosen the Capital District of New York state. Through the use of a multiobjective routing model, we can identify the entire set of nondominated routes in a network when there are multiple criteria which form the basis for route evaluation. Adopting different perspectives on this set of criteria allows us to focus on the "pros and cons" of various routing options which may be favored by different stakeholders in the process, and to identify effective routing controls (restrictions, designations or curfews) which might be used to modify the overall flow pattern of hazardous materials in the region.

THE CASE STUDY SETTING

The specific context for this analysis involves transportation of hazardous wastes in the Albany-Schenectady-Troy (Capital District) region of New York state. This region comprises approximately 300 square miles, with a total population (1990 census) of approximately 800,000 persons. The area lies on major east-west and north-south routes that connect New England and Quebec with industrial and population centers in the eastern United States. A map of the Albany-Schenectady-Troy region is shown in figure 1.

A coded network representing the major roads in this region is shown in figure 2. The node numbers given in the figure indicate specific points of interest for this routing analysis. Near node 42 (the end of I-787, at NY 32 in Cohoes) is a hazardous waste treatment facility that treats mostly spent solvents and other liquid wastes which are transported in bulk. Truck traffic transporting wastes into this facility enters the region at the five nodes shown in table 1. The table also gives the volume of wastes that entered at each node in 1988, based on manifest data from

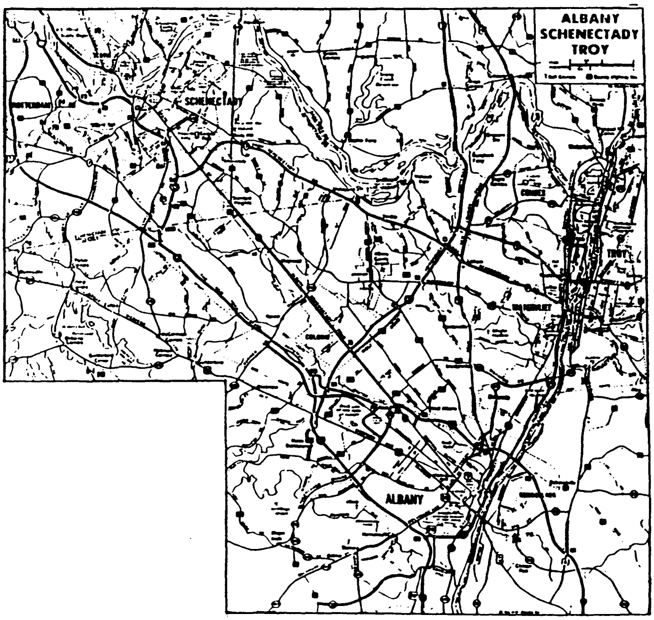


Figure 1. Road map of Albany-Troy-Schenectady region.

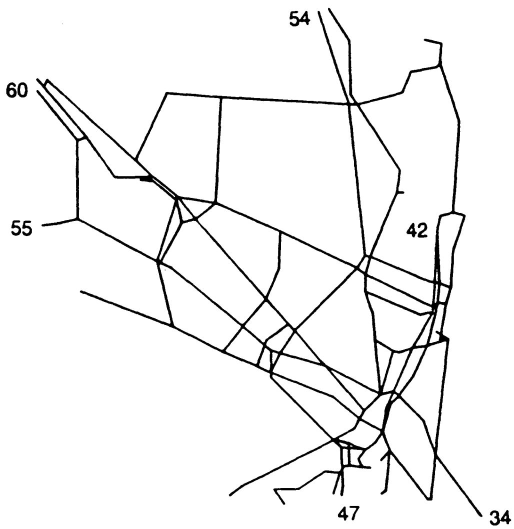


Figure 2. Road network of Albany-Troy-Schenectady region.

the New York Department of Environmental Conservation (DEC).

Table 1. Volume of hazardous waste destined for treatment at node 42, by origin node.

Origin	Description	1988 tons
34	I-90 from the east	5,418
47	I-87 from the south	5,187
54	I-87 from the north	167
55	I-88 from the southwest	7
60	I-90 from the west	1,942

We will consider routing options for trucks from these five origins to node 42, paying special attention to the three largest origins. The database for the analysis contains several different measures for each link in the network, including:

1. Length (miles)
2. Travel time (minutes)
3. Estimated truck operating cost, based on length and travel time ($)
4. Estimated accident rate per truck trip
5. Estimated population residing within one-half mile on either side of the link, based on 1990 census data
6. Number of schools within one-half mile on either side of the link

The formula used for estimating truck operating costs is based on earlier work by Abkowitz et al. (1984). Many different truck operating cost models are available, and the choice of this particular one is not crucial to the analysis. It simply provides a convenient representation of operating costs in terms of other link data which are easily available (length and travel time).

The estimated rate of accidents (per truck trip) is based on hazardous materials release accident rates for various roadway classes, as cited by Harwood and Russell (1990). For our analysis, the accident *rate* (per million vehicle-miles) has been converted to an accident rate per truck trip over each link by multiplying by the length of the link and dividing by 1,000,000.

The estimated population residing within one-half mile of each link was constructed using 1990 census figures for individual census tracts in the area, and assuming that the population in each tract is uniformly distributed across its area. While this is not really true, the tracts are small relative to the size of the analysis area (there are 182 tracts in the analysis area), so the error created by the approximation is not large.

The number of schools within one-half mile of each link was determined by locating each school in the area on a large map, and then counting schools within the established bandwidth around each link.

The choice of one-half mile on either side of the link as the definition of the bandwidth of interest, for both population and schools, is somewhat arbitrary. For many types of hazardous materials, the effects of a release accident would be confined to the roadway and immediately adjacent right-of-way, with negligible risk to population in the surrounding area. For other types of materials, the potential exposure of surrounding-area population is of much greater concern. We have included this measure in our analysis to illustrate its effects on route choice, but we recognize that the importance of this measure depends on the nature of the material being analyzed.

THE POLICY FOCUS OF THE ANALYSIS

Using multiobjective routing analysis software (Wijeratne, 1990), we can find all nondominated routes between any pair of nodes, using a set of criteria. In order not to make this paper too long, we will not describe the software or the mathematics of the underlying multiobjective network methods here. The interested reader is referred to the papers mentioned above for those details. In this analysis, we have focused on measures 3-6 from the previous section:

- Operating cost
- Accident rate
- Population exposure
- Number of schools in exposure area

Then we can identify a number of policy objectives, based on various combinations of these measures. As two examples, we consider the following:

1. Minimize the accident rate, subject to not forcing the carriers to incur more than a 50% increase in operating cost, relative to the lowest cost route

2. Minimize risk exposure, by focusing on a combination of population exposure and number of schools within one-half mile of the route

It is clear that these two policy objectives do not exhaust the range of possible concerns or potential objectives. However, they do illustrate the types of objectives which are likely to be realistic, and they represent different types of multiobjective analyses. In the first case, we want to minimize one criterion, subject to a constraint on another. In the second case, we are explicitly focusing on combinations of two objectives, but without specifying relative weights or values on them. This second case could easily be generalized into more than two dimensions as well, but for clarity of exposition, we will only consider two-dimensional tradeoffs for now. We do want to emphasize, however, that routing analysis tools that can handle several criteria simultaneously are vital to thorough policy analyses of this type, and that the methods we have developed are able to do this effectively.

For each of the major origin nodes (34, 47 and 60) indicated in table 1, we determine all the nondominated routes to the treatment facility at node 42, using the four measures listed above. We then analyze how each of the policy options might influence the choice of route(s) from those in the nondominated set, and what implications different public policy directives might have for route restrictions and/or designations.

ANALYSIS OF ROUTING OPTIONS FROM NODE 34

Node 34 lies at the eastern edge of the network where I-90 enters the Capital District from the east. In 1988, 5,418 tons of hazardous wastes entered here bound for the treatment facility at node 42.

The multiobjective routing analysis finds nine paths as nondominated combinations of the four objectives listed in the previous section. The nine paths, whose characteristics are listed in table 2, are actually variations of three basic routing options, which are shown in figure 3. The "A" route in figure 3 minimizes both operating cost and accident rate. The "B" route minimizes population exposure by "looping around" Troy through Latham. The "C" route minimizes the school exposure by making a wider loop around Albany.

Figure 4 illustrates the tradeoffs for all nine routes between the number of schools exposed and the population exposure. We notice that although the "C" routes minimize school exposure, they have much larger population exposure than the "A" or "B" routes. Thus, even within policy option 2, which aims to minimize exposure, there is a significant tradeoff among routes because two different measures of exposure lead to different route choices.

In this case study, the minimum cost route is also preferable from one public policy perspective—that of minimizing the accident rate. Furthermore, the differences in accident rate and operating cost between the "A" route and the "B" routes are quite substantial. Route 3, for example, from the "B" group, has a 9% lower population exposure than the "A" route (see table 2), but its accident rate is 160% higher and its operating cost is 62% higher.

One conclusion from this kind of result is that public policy should not be too forceful about pursuing single objectives, like minimizing population exposure, without studying the implications carefully. In this instance, at least for most materials, the increase in accident rate associated with minimizing population exposure would be a poor tradeoff as shown by route 5 in table 2.

Table 2. Summary of routes from node 34 to node 42.

Route	Group	Operating Cost	Accident Rate Per Trip	Population Exposure	Number of Schools
1	A	\$33.80	3.52×10^{-6}	36,500	7
2	B	\$49.80	8.02×10^{-6}	38,100	6
3	B	\$54.70	9.15×10^{-6}	33,300	5
4	B	\$52.60	8.02×10^{-6}	39,200	6
5	B	\$57.50	9.15×10^{-6}	34,300	5
6	C	\$67.70	6.57×10^{-6}	65,600	5
7	C	\$67.30	5.63×10^{-6}	65,700	5
8	C	\$71.00	9.72×10^{-6}	60,500	4
9	C	\$70.60	8.79×10^{-6}	60,600	4

This example also illustrates a situation in which it may be good public policy to "do nothing," at least in the sense of restricting or designating routes. Since the minimum cost route also minimizes accident rate, carriers are likely to follow that route in their own self-interest, and further regulation is unlikely to be necessary.

ANALYSIS OF ROUTING OPTIONS FROM NODE 47

Node 47 lies at the southern edge of the network where I-87 enters the Capital District from the south. In 1988, 5,187 tons of hazardous waste entered here bound for the treatment facility at node 42.

A total of five paths were found as nondominated combinations of the four criteria (see table 3), but they can be grouped into two basic routing options, shown as "A," and "B" in figure 5. The "A" route (via I-787) actually contains three variations, and the "B" route (I-87 to NY 7, and then onto I-787) contains two. In this case, route 1 (from the "A" group) minimizes both operating cost and accident rate, while route 4 (from the "B" group) minimizes population exposure and the number of schools within the exposure area.

This case is different from the previous one (origin node 34) in at least three important respects. First, there is substantial variation within a group ("A") in one of the measures (accident rate). Second, the differences in population exposure across all the routes are relatively small. Third, there are substantial differences between the groups in the number of schools in the exposure area.

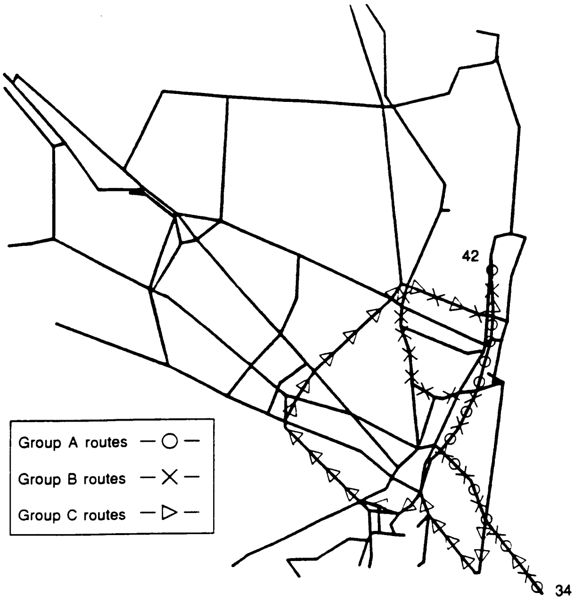


Figure 3. Illustration of major routing options from node 34 to node 42.

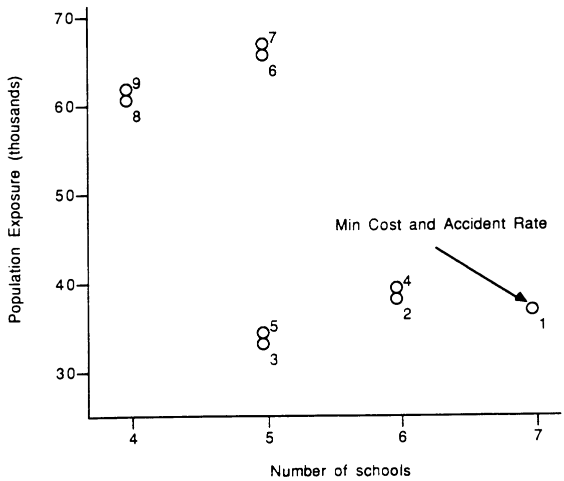


Figure 4. Population exposure - school tradeoffs for routes from node 34 to node 42.

Table 3. Summary of routes from node 47 to node 42.

Route	Group	Operating Cost	Accident Rate per Trip	Population Exposure	Number of Schools
1	A	$35.00	3.59×10^{-6}	59,000	9
2	A	$37.30	6.80×10^{-6}	58,600	9
3	A	$39.50	7.96×10^{-6}	57,700	11
4	B	$49.30	5.40×10^{-6}	52,300	3
5	B	$48.90	4.47×10^{-6}	52,400	3

There are large differences in accident rates among the routes in the "A" group. The differences arise because this particular measure is very sensitive to roadway type and conditions at specific locations. As a result, what appear to be minor variations in routing can have significant effects on accident rate. This understanding may point to a useful focus for route restrictions—keep hazardous materials trucks away from specific locations that have a history of high accident rates.

A second conclusion from this case is that time-of-day restrictions may be effective in some instances. The larger number of schools in the potential exposure area along route 1, for example, is of little concern if the shipment is passing at night, when there are no students present. Thus, a reasonable public policy in this case may be to prohibit daytime movements on one or two links along route 1 which pass several schools, leaving carriers the option of either adjusting their route during the day, or adjusting their schedules to move at night.

ANALYSIS OF ROUTING OPTIONS FROM NODE 60

Node 60 lies on the western edge of the network where I-90 enters the Capital District from the west. In 1988, 1,942 tons of hazardous wastes entered here bound for the treatment facility at node 42.

A total of 25 paths were found as nondominated combinations of the four criteria indicated in the previous section. Three basic groups can be identified, each of which contains several minor variations. Table 4 shows the characteristics of a representative route from each group, and figure 6 illustrates their alignment. The "A" route in figure 6 is the minimum cost alternative. It follows the most direct path through the network—through downtown Schenectady, east on NY 7 through Latham and then north on I-787 to the treatment facility.

The "B" route in figure 6 minimizes both the accident rate and the number of schools in the potential exposure area. It follows the thruway (I-90) southeast, then

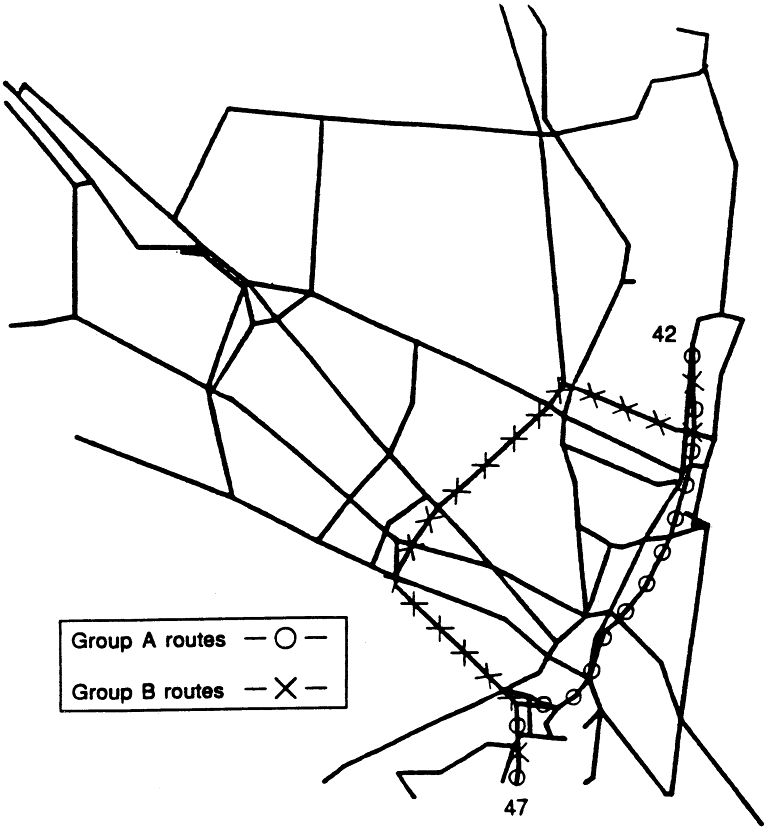


Figure 5. Illustration of major routing options from node 47 to node 42.

goes north on I-87 to I-787, and follows I-787 to the destination. Because this route is almost entirely on interstate highways, the accident rate is the lowest of all the alternatives in the set of possible routes and there are few schools adjacent to the route.

Table 4. Summary of routing options from node 60 to node 42.

Route	Group	Operating Cost	Accident Rate per Trip	Population Exposure	Number of Schools
12	A	\$69.00	1.14×10^{-5}	58,800	15
2	B	\$72.60	4.87×10^{-6}	36,400	2
23	C	\$93.80	1.74×10^{-5}	23,800	7

The third route ("C") in table 4 minimizes population exposure. It goes across NY 146 through Clifton Park. Figure 7 shows a two-dimensional plot of all 25 possible routes, focusing on population exposure and number of schools. The three routes from table 4 are identified in the figure, and we see how the "B" and "C" routes define the "efficient frontier" in this two-dimensional view of the alternatives.

From a public policy perspective, it is desirable to divert hazardous materials traffic away from the "A" route. Compared with the "B" route, it produces only a 5% savings in cost in exchange for a 135% increase in accident rate and a 57% increase in population exposure. Moreover, while the "C" route produces a 53% decrease in population exposure compared with the "B" route, it also results in a 250% increase in accident rate, and a 26% increase in cost. Moreover, this route passes through an area of high population growth, so the fact that it minimizes population exposure may be only a short term phenomenon. Finally, this route also passes through a very high hazard location, an at-grade signalized intersection, which has among the highest accident rates for all signalized intersections in the Capital District. This fact is not reflected in the database because high-accident location information was not included. If society accepted this logic, the next question would be how to bring about the desired change in routing from the minimum cost ("A") route to the "B" route. A route designation would be possible, or a ban on the use of one or more links in the "A" route could be instituted. Let us explore the latter option. Use of the "A" route could be eliminated by adopting a ban of one or more links along the four-lane, tight geometry section of NY 7 where a "high speed" truck accident could cause significant damage. One of these links also passes beneath the most heavily-used approach to the local commercial airport. Planes cross overhead at no more than 500-1000 feet.

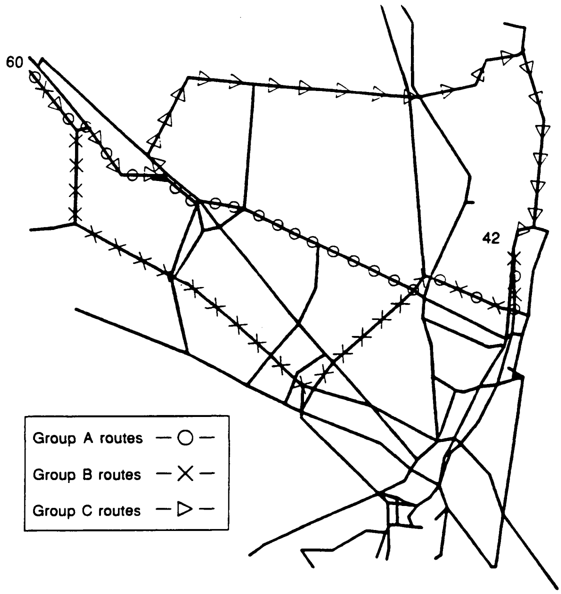


Figure 6. Illustration of major routing options from node 60 to node 42.

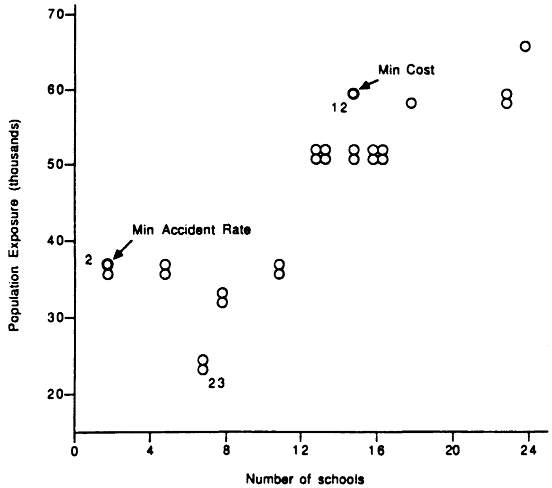


Figure 7. Population exposure - school tradeoffs for routes from node 60 to node 42.

At the eastern end of this section of NY 7, many commercial trucks use the link to reach distribution centers immediately adjacent to I-87. The ban would have to be carefully worded so that these truckers were not adversely affected.

But banning the use of a link along NY 7 might not be sufficient to get trucks to use the "B" route. If prohibited from a section of NY 7, truckers might choose an alternate route down NY 5 (Central Avenue). Since Central Avenue is also an undivided, heavily congested multilane arterial, it would have the same kinds of drawbacks as NY 7. However, the drawbacks would be more severe because it has much heavier traffic volumes and numerous shopping centers and driveways. A ban on the use of one or more links along NY 5 might also be necessary.

We draw several conclusions from this analysis. First, a ban on the use of selected links is a feasible control strategy. Second, a ban on more than one link may be necessary in order to preclude routes that were not in the initially established set of nondominated routes. These routes could emerge as attractive choices if the direct route option were eliminated for some reason. Third, a ban on the use of links in the "C" route would only be necessary if it became evident, after banning use of selected links in the "A" route, that truckers were electing to use the northerly ("C") route rather than the southerly ("B") one.

CONCLUSIONS AND RECOMMENDATIONS

Some significant conclusions can be drawn from these analyses. We think the most important one is that a micromanagement of routing choice by the trucking firms may not be necessary. Route designation may not be required. Pruning a few links from the network where hazardous material truck traffic is undesirable may well be sufficient. It allows the carrier significant latitude in making routing decisions while protecting the public interest and, in that vein, it allows the carrier flexibility for real-time decision making (e.g., selection of alternate routes when accidents, weather, water main breaks, and other incidents occur that make use of the normal route impossible or unacceptable).

The analysis also suggests that it may be possible to regulate use of the network on an exception basis, precluding the use of links only when it is known that truckers might want to use them. We analyzed routing options for 98.7% of the tonnage coming to the treatment plant at node 42 and found that only two or three link-use bans might be required.

In conclusion, we have illustrated that a real-world multiobjective routing analysis can be conducted and that it can yield useful results. We have examined tradeoffs in risk-related measures (population and the number of schools exposed), and their relationship to incident (accident) likelihoods. Several scenarios and routing regulations have been considered and the conclusion reached that regulation by exception may be sufficient. Route designations are not necessarily required to achieve socially desirable routing solutions.

Multiobjective routing tools, such as we have developed, make the analysis feasible and tractable. In fact, we would argue that a multiobjective framework is indispensible to this type of problem.

It is also important to note that, through this type of analysis, carriers can become aware that offering to work for the improvement of specific network links may be in their best interest. They can avoid circuitous routing restrictions as a result. The emphasis should not always be on link bans but on link enhancements as well. Carriers can also see from this analysis the type of analysis public policy leaders would expect to see conducted if they (the carriers) were arguing for permission to use a given route link.

From society's perspective as a whole, a comprehensive methodology is emerging to deal with the complex, multiobjective task of making high quality decisions for the safe shipment of both hazardous materials and wastes.

REFERENCES

Abkowitz, M., A. Eiger and S. Sirinivasan. 1984. "Estimating the Release Rates and Costs of Transporting Hazardous Waste." *Transportation Research Record* 977:22-30.

Harwood, D. and E. R. Russell. 1990. *Present Practices of Highway Transportation of Hazardous Materials.* Report, FHWA-RD-89-013, Federal Highway Administration, Washington, D.C.

Turnquist, M. A. 1987. "Routes, Schedules and Risks in Transporting Hazardous Materials." In B. Lev et al., eds., *Strategic Planning in Energy and Natural Resources.* North-Holland, Amsterdam, 289-302.

Wijeratne, A. B. 1990. *Routing and Scheduling Decisions in the Management of Hazardous Material Shipments.* PhD dissertation, Cornell University, Ithaca, N.Y.

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9

SITING EMERGENCY RESPONSE TEAMS: TRADEOFFS AMONG RESPONSE TIME, RISK, RISK EQUITY AND COST

George F. List

ABSTRACT

This paper describes a model capable of recommending sites for hazardous materials (hazmat) emergency response teams when the primary concern is over transportation-related incidents and when multiple objectives are involved. A large-scale urban area is used as a case study to illustrate the model's use and the insights it can provide. The model's most notable features are: (1) its ability to be used both for horizon year and staged decision making, (2) its microcomputer implementation, and (3) its use of a risk function sensitive to response time as well as incident rates and population distribution.

INTRODUCTION

Emergency response is an important part of a community's defense against hazmat transportation incidents. The U.S. Department of Transportation (DOT) estimates that more than 500,000 shipments occur nationwide on a typical day, and that over 4 billion tons move annually.

Following recommendations from the Office of Technology Assessment (1986), the federal Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA) calls for the expenditure of $30 million over six years for states to develop emergency response plans and $54.8 million for response training and curriculum development. Specifically, section 117A of HMTUSA calls for states to comply with the Emergency Planning and Community Right-to-Know Act of 1986, including (1) determination of flow patterns of hazardous materials within and between states and (2) the need for regional hazardous materials response teams if they want to receive funds for public sector training and planning.

This paper discusses how such planning should proceed. Assuming the spirit of of the 1990 act is followed, the paper tries to determine how many response teams should be established in a typical urban area and where they should be located.

EVALUATING SITING OPTIONS

In the process presented here, sites are chosen so that certain objectives are minimized, such as the average and maximum response time, and the average and maximum levels of risk imposed. This is done based on the characteristics of the sites available, the hazmat flow patterns, the accident and incident probabilities for the network, and the region's population distribution. This can be illustrated through an example.

An ongoing, related research project (see List, Mirchandani and Turnquist, 1990, and List and Mirchandani, 1990) has proudced a full-featured hazmat transportation database for the Capital District of New York state (the Albany-Schenectady-Troy urban area). The region covers about 300 square miles and has a 1990 population of about 800,000. It lies on major east-west and north-south routes connecting New England and Quebec with industrial and population centers in the eastern United States. A network representing the major roads in the region is shown in figure 1. It contains 124 links and 86 nodes.

Nineteen sites have been identified as possible locations for hazmat response teams. A few of these already have limited response capabilities. All are existing fire station locations. The location of these sites is shown in figure 1.

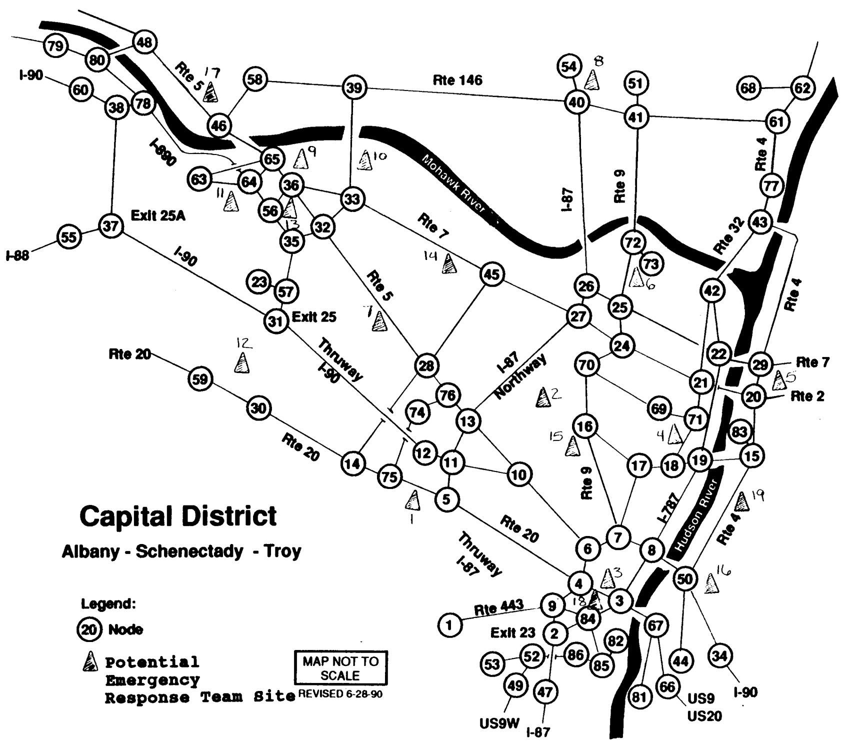


Figure 1. Potential emergency response team site locations within the network

Mathematically, the following multiobjective realization of the unconstrained facility location problem (UFL problem), as described by Mirchandani and Francis (1990), is solved:

minimize:

$$P_{avg} = (\sum_s Pop(s)*P_i(s|t_r(s),Vol(s)))/(\sum_s Pop(s))$$

$$P_{max} = \max_s (P_i(s|t_r(s),Vol(s)))$$

$$T_{avg} = (\sum_s t_r(s))/N_s$$

$$T_{max} = \max_s (t_r(s))$$

subject to:

$$t_r(s) = \min_{\delta_j=1} (t_{jr}(s)) \quad \text{for all } s$$

$$\sum_j \delta_j \leq M$$

$$\delta_j \in \{0,1\} \quad \text{for all } j \qquad (1)$$

where:

P_{avg} = average probability of injury for people within the region

P_{max} = maximum probability of injury across all link segments

T_{avg} = average response time (minutes)

T_{max} = maximum response time (minutes)

$t_{jr}(s)$ = response time from site j to segment s

$t_r(s)$ = response time for segment s (minutes)

$P_i(s|t_r(s))$ = average probability of injury for the people near link segment s given that the response time is $t_r(s)$

$Pop(s)$ = population affected by link segment s

$Vol(s)$ = volume crossing link segment s

N_s = number of segments

δ_j = choice variable indicating whether response team site j has been selected (δ_j=1) or not (δ_j=0)

M = number of response team sites that can be chosen.

The model tries to minimize all four objectives simultaneously through a generalized cost function. The first objective, P_{avg}, reflects the average probability of injury within the region. The population affected by segment s is multiplied by the average probability of injury per person in that affected population given the response time $t_r(s)$ and the volume Vol (s) passing over the segment. These (population)*(probability of injury) products are then summed for all segments s and divided by the total affected population (Σ Pop (s)) to compute the average probability of injury for the region. The second objective, P_{max}, reflects the maximum probability of injury among all segments. T_{avg} focuses on the average response time and T_{max} reflects the longest individual segment response time. For T_{avg}, the response times by segment $t_r(s)$ are summed and divided by the number of segments N_s to determine the average response time.

Response Time Values

Given the goal of determining where well-trained, full-featured hazmat response teams should be placed, the times $t_{jr}(s)$ are intended to reflect how long it would take a team to bring a "typical" incident under control. Four components are involved: notification, mobilization, transit, and containment time. The first of these indicates how long it takes to notify a response team once the incident has occurred. While this might be "instantaneous" if the vehicle is equipped with an automatic or driver-activated emergency signaling device, it could also be quite long if the incident occurs late at night and no motorists are passing by. Local hazmat response team chiefs and other experts indicate that five minutes is a reasonable expected value. Mobilization time reflects how long it takes to get an emergency response team underway once a call has been received. Again, discussions with state and local emergency response team leaders indicate that this value is at or under three minutes. There is a difference between the time for the first unit to be dispatched versus the whole team, and the three-minute value reflects the latter. Transit time is how long it takes to travel from the response team site to the scene of the incident. This can be computed based on the path the response team follows to reach the incident location. The model employed here assumes a speed of 30 MPH on secondary roads, 45 MPH on major arterials and 60 MPH on freeways. Containment time is how long it takes to contain the contaminant once the incident scene is reached. This component has great variability and is highly dependent on the nature of the incident. No data exist to indicate how long this typically is. Fifteen minutes has been assumed for the analysis presented here, but much longer times are clearly possible.

The computer program used to solve equation (1), and provide the siting recommendations, is microcumputer-based and follows the generalized interchange heuristic described by Cornuejols, Nemhauser, and Wolsey (1990). The four objectives (P_{avg}, P_{max}, T_{avg}, T_{max}) are combined using weights w_i, where $\Sigma w_i = 1$, to form a generalized cost function. A "greedy heuristic" is used to add sites one at a time based on the best possible improvement in the combined objective function and, after adding a given site, a "two-opt" interchange checks to see if one-for-one site substitutions can improve the objective function further. The interchange step is omitted when one wants to determine how to sequence the opening of a preselected set of sites. The problem is solved many times over, with different combinations of weights w_i to identify all nondominated solutions.

The Site, Network and Zonal Databases

Three databases provide the inputs needed by the model. The first of these, the site selection database, contains the location of each potential site, the team mobilization time, the network access nodes, one or more, and the times required to reach those nodes. This information is displayed in table 1 for the Capital District network.

The zonal database has three elements for each zone: (1) population, (2) area, and (3) centroid location (x,y). Typically, a zone is a census tract., although exceptions exist under two conditions. First, if one or more links pass through the tract, a subdivision is made so that the resulting zones lie within the polygons formed by the original tract boundary and the intersecting links. Second, if the population distribution is not uniform, the tract is subdivided so that the new, finer-grained zones more accurately reflect the built-up areas. Each zone's centroid is always at its population-mass center. The number of zones in the Capital District database is 177, containing a total population of 569,811. The average population per zone is 3,220.

The network database divides the links into link segments. The number of segments per link depends principally on changes in directional alignment and functional class. The Capital District's link database contains 178 link segments derived from 124 links. The maximum number of segments per link is six for this database. The average is 1.4, so many links have only one segment. The link database contains seven data items for each segment: (1) beginning node, (2) end node, (3) beginning node location (x,y), (4) end node location (x,y), (5) travel time, (6) incident probability, and (7) probability of injury for people living within the geographic area affected by the segment. The incident probabilities depend on functional class and are derived from the truck incident rates developed by Harwood and Russell (1990). The applicable Harwood-Russell rate (per million vehicle-miles) is multiplied by the segment length and divided by 10^6 to yield a per-unit-passage incident rate. Since the resulting rate is very small, it is acceptable to treat it as the probability of an incident occurring on the segment during a given trip.

To estimate the probability of injury for each segment, and to assess the sensitivity of this probability to response time, an impact assessment submodel (IAM) combines the probability-of-injury model presented by Abkowitz and Cheng (1990) with the segment -to-zone impact assessment methodology described by List and Mirchandani (1990). The Abkowitz/Cheng model computes the probability of injury for people within a given geographic area given an incident at a particular location and the List/Mirchandani methodology allows these probabilities to be combined based on the likelihood that the vehicle will be at any given location along the segment. Moreover, since exposure time is an explicit variable, one can estimate

TABLE 1: Response Team Site Data

Site Num.	Mobil. Time	Access Time	Access Node	Location Municipality	Location Address
1	3.00	1.25	11	Guilderland	Western Avenue & Brookwood
2	3.00	2.16	10	Loudonville	Sand Creek Road & Myers Drive
3	3.00	2.27	2	Albany	Delaware & Federal
4	3.00	0.95	21	Watervliet	Watervliet-Shaker & Whitehall
4	3.00	2.95	22	Watervliet	Watervliet-Shaker & Whitehall
4	3.00	3.37	19	Watervliet	Watervliet-Shaker & Whitehall
5	3.00	1.78	20	Troy	State & Sixth
6	3.00	2.22	25	Boght Corners	Boght Corners
6	3.00	4.44	72	Boght Corners	Boght Corners
7	3.00	1.44	28	Colonie	Central Ave & Virginia Ave
7	3.00	8.14	32	Colonie	Central Ave & Virginia Ave
8	3.00	0.72	40	Clifton Park	Fire Road & Plank Road
9	3.00	2.35	65	Schenectady	Nott & Hattie St
10	3.00	0.87	33	Niskayuna	Balltown Road & Plum
11	3.00	7.60	57	Schenectady	Broadway & Campbell Ave
12	3.00	3.00	57	Guilderland	Route 146 & Fort Hunter
13	3.00	1.32	32	Schenectady	Albany St. & Sanford
13	3.00	8.26	28	Schenectady	Albany St. & Sanford
14	3.00	5.93	27	Niskayuna	Route 7 & Winner Road
15	3.00	0.34	70	Latham	Route 9 & Austin Ave
16	3.00	1.58	31	Rensselaer	Washington Ave. & Bellview
16	3.00	3.34	50	Rensselaer	Washington Ave. & Bellview
17	3.00	1.00	46	Scotia	Mohawk Highway
17	3.00	12.00	48	Scotia	Mohawk Highway
18	3.00	1.00	3	Albany	John & S. Pearl
19	3.00	4.50	50	E. Greenbush	Ludlow & Route 4
19	3.00	7.00	15	E. Greenbush	Ludlow & Route 4

Key
Mobil. Time = mobilization time

TABLE 2: Disposal Site-Bound Volumes
The disposal site is at Node 42

From Node	Description	Volume (tons, 1988)
34	I-90 from the east	5,418
47	I-87 from the south	5,187
54	I-87 from the north	5,167
55	I-88 from the southwest	7
60	I-90 from the west	1,942

what effect changes in response time will have.

Unfortunately, it is not possible to present here all of the equations involved in the IAM submodel. But it is important to note that, while the IAM submodel is quite complex (involving logarithmic transformations, Gaussian plume distribution assessments, and evaluation of line integrals), once the impact of the maximum response time is known, such as two hours in this case, the impact of any shorter response time can be estimated using:

$$P_I(t_r) = (0.075024+0.46572*t_r)*P_I(2) \qquad R^2 = 0.9993 \qquad (2)$$

where $P_I(t_r)$ is the probability of injury for a given segment location/zone combination given that the response time is t_r and P_I (2) is the corresponding probability if the response time is two hours (i.e., no response occurs before the release ends). This is an unexpected result. A nonlinear relationship was anticipated, and the ability to generalize this finding is doubtful. But since it does pertain in this case, equation (2) can be used to estimate how the impacts change with changes in response time. Note also that since the intercept value is nearly zero (0.075), the equation nearly implies that the impact is directly proportional to response time ($P_I(t_r) = (t_r)/2*P_I(2)$).

THREE SITING SCENARIOS

Three siting scenarios are presented to illustrate the model's use. The first focuses on shipments of waste destined to a local treatment facility.

Disposal Site Analysis

In this scenario, the focus is on trucks carrying waste—basically used solvents—to a local treatment facility. The situation has many elements in common with siting response teams for the shipment of high-level radioactive waste to a repository. Specifically, the paths employed are known and set. No flows do or will exist elsewhere. The objective is to site the teams so that a particular portion of the network is well protected. For the analysis at hand, table 2 shows the volumes involved. They are derived from the 1988 manifest database kept by the New York state Department of Environmental Conservation (DEC). The shipment size is assumed to be five tons.

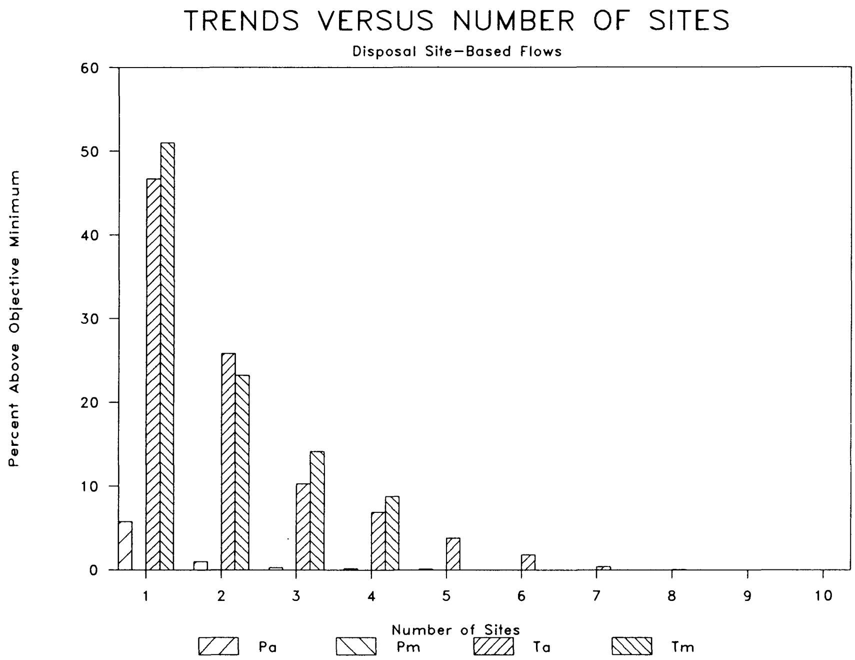
From the results of the siting analysis, the most important observation, albeit an obvious one, is that it does not take a large number of sites to reduce the objectives to near-minimum values (see table 3 and figure 2). P_{max} is minimized just by selecting site #4 (a later table shows the site selection sequences). Five sites provide the minimum for the other two objectives.

Table 3 also presents the contrast between the greedy heuristic's solutions and those obtained with the generalized interchange procedure. There are some instances

TABLE 3: Objective Function Trends for the Disposal Site-Based Flows

Number of Sites	<-----Greedy Heuristic-------> P-avg	P-max	T-avg	T-max	<----Interchange Heuristic----> P-avg	P-max	T-avg	T-max
1	104.9	3732	17.41	24.62	104.9	3732	17.41	24.62
2	100.2	3732	14.94	23.87	100.2	3732	14.94	20.09
3	99.5	3732	13.72	20.09	99.5	3732	13.09	18.61
4	99.3	3732	12.70	17.73	99.3	3732	12.70	17.73
5	99.3	3732	12.33	17.50	99.3	3732	12.33	16.30
6	99.2	3732	12.09	16.30	99.2	3732	12.09	16.30
7	99.2	3732	11.92	16.30	99.2	3732	11.92	16.30
8	99.2	3732	11.88	16.30	99.2	3732	11.88	16.30
9	99.2	3732	11.87	16.30	99.2	3732	11.87	16.30
10	99.2	3732	11.87	16.30	99.2	3732	11.87	16.30
19	99.2	3732	11.87	16.30	99.2	3732	11.87	16.30

FIGURE 2



where the latter provides a lower objective function value. For example, the greedy heuristic requires six sites to reach the minimum value for T_{max}, while the generalized interchange procedure requires only five. Since the savings from a single site might represent a significant reduction in cost, this underscores the importance of finding the optimal siting plan for a given objective or objective function combination.

Table 4 presents the optimal siting patterns provided by the generalized interchange heuristic. It is interesting to note that the siting plans for the various objectives have much in common. they use the same nine sites from the original list of 19, with only differences in selection order. In fact, for all but T_{max}, the selection order is nearly the same. For that objective, the site selection pattern tends to alter dramatically as new sites are added. This is because different combinations of sites yield different link segments as having the longest response times.

Since the percent reductions in P_{avg} and P_{max} are small, it is more interesting to focus on the tradeoffs between T_{avg} and T_{max}. As figure 3 shows, both objectives decrease dramatically as the number of sites rises from one to three. But beyond that, the gains are small. Were a decision being made on how many sites to activate, a sensible decision would be three. The T_{avg}-based, three-site solution provides the lowest T_{avg} of the two three-site options and its percents above minimum values are P_{avg}, 4%, P_{max}, 7%, T_{avg}, 10%, and T_{max}, 14%. The site combination is 6/16/18. It is interesting to note that neither site #4 nor #1, which were the two original first-choice sites, are among the three selected.

Waste-Flows-Based Analysis

In this scenario, the focus is on waste shipments through the region. It is based on a flow matrix derived from the DEC's 1988 manifest database. Table 5 and figure 4 show the effect of the number of sites selected on the objective function values obtained. All objectives except T_{max} are effectively at their minimum values if 10 sites are selected.

Table 6 shows that more variation among the siting patterns exists here than for the previous scenario, and that the union of all sites selected is much larger. It is fourteen instead of nine. Those sites never selected are 5, 11, 12, 14 and 19. It is also clear that the siting patterns for T_{max} are quite different from those for the other three objectives. This is again due to the combinatorial effect of the site choices on the maximum response time.

Since the reductions in P_{avg} and P_{max} are again small due to site additions, it is more interesting to focus on the tradeoffs between T_{avg} and T_{max} (see figure 5). A breakpoint in improvement occurs at five sites. Our recommendation would be to select the cirlced five-site option, which calls for siting pattern 4/8/13/17/18. The percents above minimum for all four objectives are as follows: P_{avg},, 2%, P_{max}, 0%, T_{avg}, 21%, T_{max}, 7%.

TABLE 4: Siting Patterns by Objective and Number of Sites Selected
Disposal Site-Based Flows/Generalized Interchange Heuristic

Objective	#S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		Site Number																		
P-avg	1				x															
	2				x														x	
	3				x												x		x	
	4				x		x										x		x	
	5			x	x		x										x		x	
	6	x		x	x		x										x		x	
	7	x		x	x		x		x								x		x	
	8	x		x	x		x		x	x							x		x	
	9	x		x	x		x		x	x						x	x		x	
P-Max	1				x															
T-avg	1	x																		
	2	x																	x	
	3						x										x		x	
	4	x					x										x		x	
	5	x					x		x								x		x	
	6	x			x		x		x								x		x	
	7	x			x		x		x	x							x		x	
	8	x		x	x		x		x	x							x		x	
	9	x		x	x		x		x	x						x	x		x	
T-max	1	x																		
	2															x	x			
	3	x					x										x			
	4	x					x			x							x			
	5			x			x		x	x							x			

FIGURE 3

AVERAGE VERSUS MAXIMUM RESPONSE TIME

Disposal Site-Based Flows

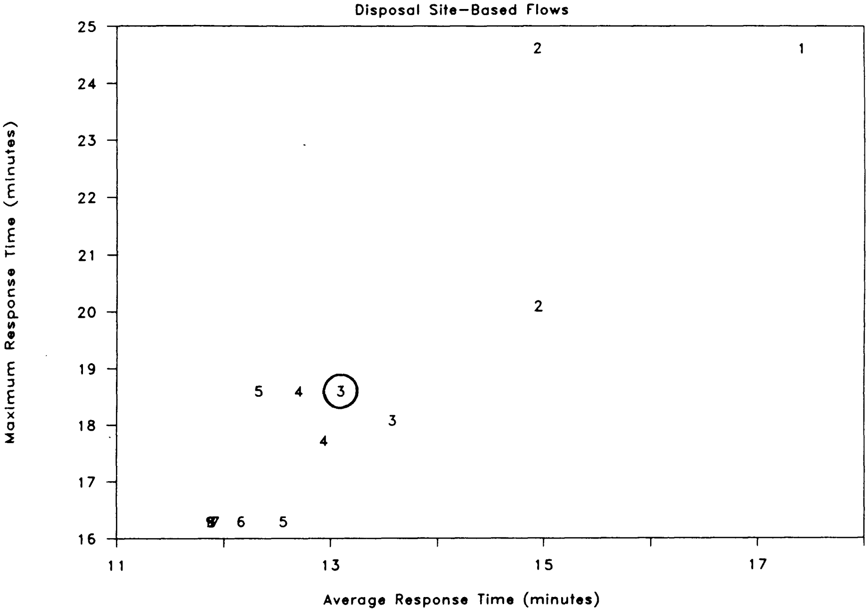


TABLE 5: Objective Function Trends for the Waste-Based Flows

Number of Sites	Greedy Heuristic P-avg	P-max	T-avg	T-max	Interchange Heuristic P-avg	P-max	T-avg	T-max
1	161.6	3220	19.94	35.24	161.6	3220	19.94	35.24
2	156.8	3220	17.76	32.45	156.8	3220	16.99	30.84
3	152.2	3220	15.93	30.84	152.2	3220	15.39	26.05
4	151.1	3220	14.65	29.41	151.1	3220	14.37	25.01
5	150.8	3220	13.71	27.98	150.8	3220	13.71	22.33
6	150.7	3220	13.18	23.49	150.7	3220	13.18	21.37
7	150.5	3220	12.86	23.12	150.5	3220	12.86	21.18
8	150.4	3220	12.57	22.58	150.4	3220	12.57	19.85
9	150.4	3220	12.35	21.75	150.3	3220	12.35	19.85
10	150.3	3220	12.14	20.35	150.3	3220	12.14	19.85
19	150.3	3220	11.46	19.85	150.3	3220	11.46	19.85

FIGURE 4

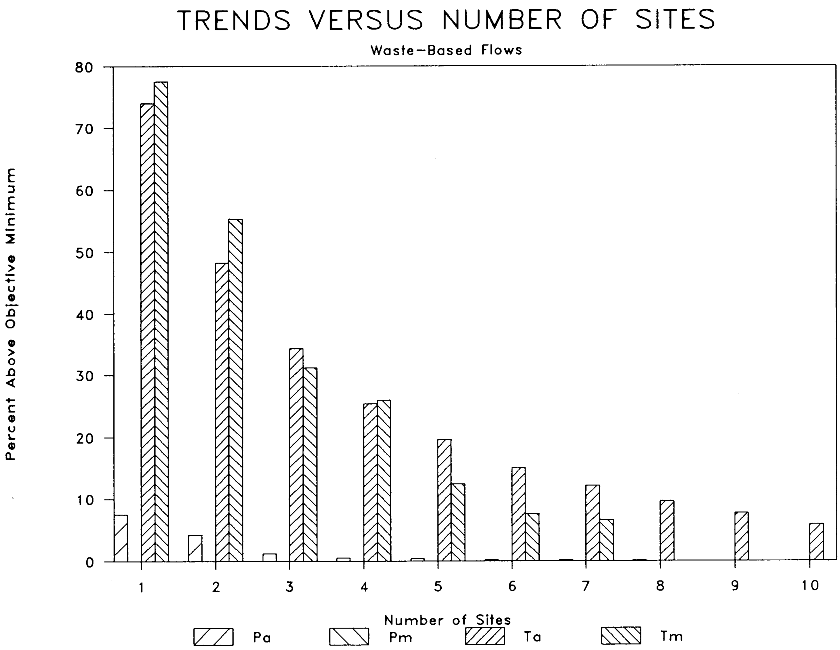
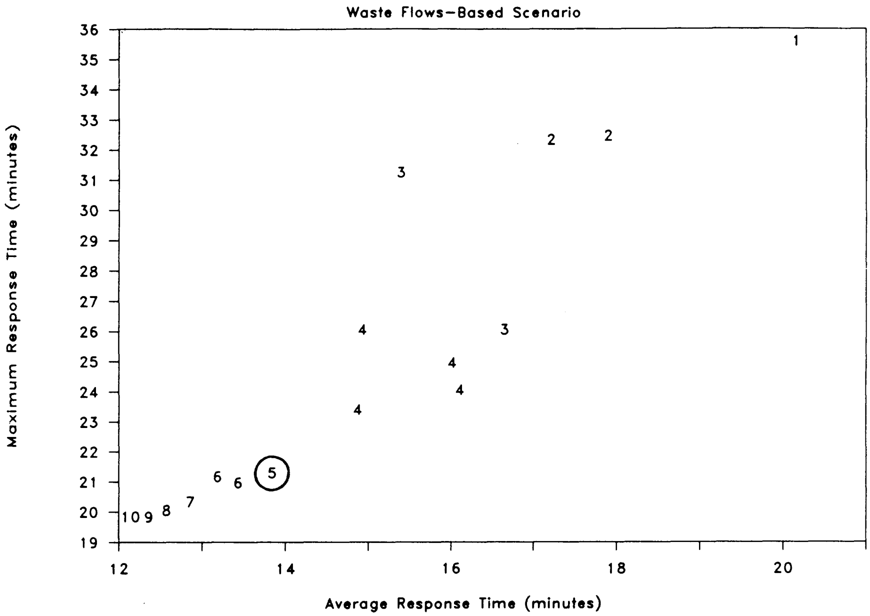


TABLE 6: Siting Patterns by Objective and Number of Sites Selected
Waste Shipment-Based Flows/Generalized Interchange Heuristic

Objective	#S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
P-avg	1																		x	
	2				x														x	
	3	x			x														x	
	4	x			x												x		x	
	5	x	x		x												x		x	
	6	x	x	x	x												x		x	
	7	x	x	x	x									x			x		x	
	8	x	x	x	x				x					x			x		x	
	9	x	x	x	x				x	x	x						x		x	
	10	x	x	x	x		x		x	x	x						x		x	
P-Max	1				x															
T-avg	1	x																		
	2													x					x	
	3								x					x					x	
	4				x				x					x					x	
	5	x			x				x					x					x	
	6	x			x				x					x				x	x	
	7	x			x				x					x		x		x	x	
	8	x			x				x					x		x	x	x	x	
	9	x			x			x	x					x		x	x	x	x	
	10	x			x			x	x	x				x		x	x	x	x	
T-max	1										x									
	2	x																x		
	3															x	x	x		
	4	x					x									x	x			
	5	x			x				x								x	x		
	6			x	x			x	x								x	x		
	7				x			x	x	x							x	x	x	
	8				x		x	x	x	x							x	x	x	

FIGURE 5

AVERAGE VERSUS MAXIMUM RESPONSE TIME



Functional Class-Based Analysis

This scenario considers a situation where the link volumes are related strictly to functional class. It is a surrogate for examining total hazmat flows through the region. It is assumed that the link volumes within a given class are nearly the same while major differences exist between classes. The situation is represented by setting the volumes on the freeway links to N1 truck movements per year, the arterials (one way, divided or undivided) to N2«N1, and the two lane facilities to N3«N2.

Assuming N1 = 4,000, N2 = 400, and N3 = 40, table 7 and figure 6 show the trends in objective function achievement versus the number of sites selected. Of most interest in this scenario are the differences in siting patterns vis a vis the waste-based analysis insofar as P_{avg} and P_{max} are concerned. The patterns for T_{avg} and T_{max} are the same because no aspect of network topology has changed. Comparing table 8 with table 6, it can be seen that sites 2 and 3 have "x's" in the same category, but with the situation reversed. Sites 15 and 13 are also similar. Site 13, for instance, has five x's in table 8 while in table 6 it has only two. The remaining sites with differences are 8, 9, and 10, relating to the "earliness" with which they are chosen. In table 8 they are chosen much earlier than in table 6.

SUMMARY AND CONCLUSIONS

This paper has focused on the problem of siting emergency response teams intended to protect against hazardous material incidents. Response time has been a major factor in the analysis. It has been shown that it is possible to incorporate response time into the analysis framework and that its value can be significant. Had response time not been included, it would have been impossible to assess quantitatively the value of selecting one siting pattern versus another, except through the minimization of response time. Moreover, the differences in siting patterns between minimizing risk and minimizing response time are significant, especially when the number of sites is small.

It has also been shown that for the area used as a case study, only three to five teams are required to effectively reach the minimum values possible were all 19 potential sites to be selected. However, to achieve this, the locations of the teams must be carefully chosen, and in this context, the multiobjective analysis methodology employed plays a critical role. It allows identification of the tradeoffs among objectives, using nondominated or efficient alternatives only, and allows examination of these tradeoffs in a graphical manner. While no one siting plan is ever optimal for all objectives at once, suitable compromise solutions can be identified.

Issues which yet remain unexplored are several. First, no attention has been given to the effect of external response teams, such as those that are part of the ChemNet network maintained by the chemical industry. The hierarchical focus here has been on determining what subset of the existing fire dapertments would be ideally located for dealing with highway-related hazmat incidents.

Second, no consideration has been given to the differences between paid and

TABLE 7: Objective Function Trends for the Functional Class-Based Analysis

Number of Sites	<-----Greedy Heuristic------->				<---Interchange Heuristic----->			
	P-avg	P-max	T-avg	T-max	P-avg	P-max	T-avg	T-max
1	1092.9	4578	19.94	35.24	1092.9	4578	19.94	35.24
2	999.3	4578	17.76	32.45	999.3	4578	16.99	30.84
3	979.9	4578	15.93	30.84	979.9	4578	15.39	26.05
4	965.9	4578	14.65	29.41	965.9	4578	14.37	25.01
5	954.0	4578	13.71	27.98	954.0	4578	13.71	22.33
6	947.1	4578	13.18	23.49	947.1	4578	13.18	21.37
7	943.8	4578	12.86	23.12	943.7	4578	12.86	21.18
8	941.3	4578	12.57	22.58	941.3	4578	12.57	19.85
9	939.3	4578	12.35	21.75	939.2	4578	12.35	19.85
10	937.8	4578	12.14	20.35	937.7	4578	12.14	19.85
19	934.0	4578	11.46	19.85	934.0	4578	11.46	19.85

FIGURE 6

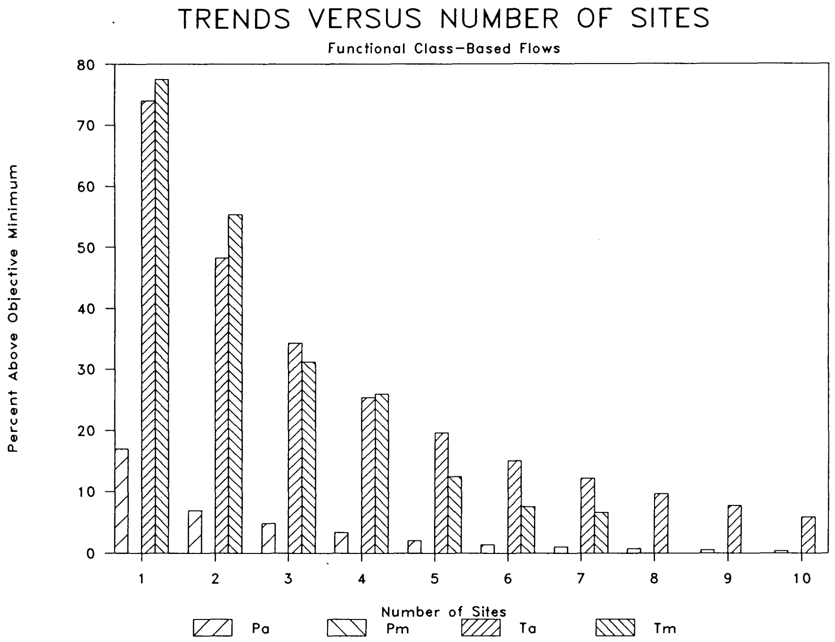


TABLE 8: Siting Patterns by Objective and Number of Sites Selected
Functional Class-Based Flows/Generalized Interchange Heuristic

		Site Number																		
Objective	#S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	1																		x	
	2													x					x	
	3				x									x					x	
	4	x			x									x					x	
P-avg	5	x			x									x				x	x	
	6	x			x				x					x				x	x	
	7	x			x				x	x	x							x	x	
	8	x			x				x	x	x					x		x	x	
	9	x			x				x	x	x					x	x	x	x	
	10	x		x	x				x	x	x					x	x	x	x	
P-Max	1																x			

Note
T-avg and T-max are as for the Waste-Based Scenario

volunteer forces. Their mobilization times are somewhat different. A sensitivity analysis focusing on this one variable would provide useful insights about how many teams would be required if the response sites that are presently all-volunteer remain so. Implicitly, by setting the mobilization times for all candidate sites to three minutes, it has been assumed either that all sites will be professionally staffed or that a sufficient number of volunteers will always be on hand to fully staff the response equipment.

From the various scenarios, it can be seen that while the site selection sequence does vary among objectives, it ultimately tends to converge to the same basic set of sites, long before all sites are employed. This suggests that enough "collinearity"exists among the objectives that, in the long run, minimizing one tends to minimize the others. Where this is not true is for the minimax objectives, where in many instances the selection of just one site is sufficient to achieve the optimal value. In the scenarios considered, this one-site solution does not provide the minimum solution nor is it likely to do so in general.

The final issue to highlight is that concerning containment time. This is the time required to stop further release of the contaminant or damage in general once the incident scene has been reached. Data on a proper value for this component of response time is quite limited. Yet it has a major effect on the solution. The longer it is, the less important the variation in response time becomes. If the response team manages to reach the site in 15 minutes, but it takes two hours to stop further release of the material, the main value in being quick to reach the scene is principally to take charge. It is therefore important to determine more precisely: (1) the types of incidents where a speedy response can have a demonstrable effect on the severity of the incident that ensues, (2) the nature of those effects, and (3) the range of response times that are required to have a significant effect.

In conclusion, a real world multiobjective siting analysis has shown that the model can be used to yield useful results. Tradeoffs have been examined in risk-related measures ranging from the average response time to the maximum per unit population risk exposure. Several scenarios and siting options have been considered with the conclusion that a multiobjective approach to the problem provides helpful insights into proper selection of sites, particularly when a limited number must be chosen. Through the document, carriers and shippers can become aware of the issues involved in emergency response and take actions that ensure their positive perception in the eyes of the public and from society as a whole, and, in general, a comprehensive methodology is emerging to deal with the complex, multiobjective task of making high-quality decisions for the safe shipment of both hazardous materials and wastes.

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REFERENCES

Abkowitz, M., and P. Cheng. 1988. "Developing a Risk-Cost Framework for Routing Truck Movements of Hazardous Materials." *Accident Analysis and Prevention*, pp. 39-51.

Cornuejols, G., G. Nemhauser, and L. Wolsey. 1990. "The Uncapacitated Facility Location Problem." In P. Mirchandani and R. Francis, eds., *Discrete Location Theory*. J. Wiley & Sons, Inc., New York, N.Y.

Harwood, D., and E. Russell. 1990. *Present Practices of Highway Transportation of Hazardous Materials.* Report FHWA-RD-89-013, Federal Highway Administration, Washington, D.C.

List, G., P. Mirchandani, and M. Turnquist. 1990. *Logistics for Hazardous Materials Transportation: Scheduling, Routing and Siting.* First year interim report prepared for the Region II University Transportation Research Center, June.

List, G., and P. Mirchandani. 1991. "An Integrated Network/Planar Multi-Objective Model for Routing and Siting for Hazardous Materials and Wastes." *Transportation Science* 25 (2): 146-56.

Mirchandani, P., and R. Francis. 1990. *Discrete Location Theory.* J. Wiley & Sons, Inc., New York, N.Y.

Office of Technology Assessment. 1986. *Transportation of Hazardous Materials.* U.S. Government Printing Office, Washington, D.C.

10

DATABASES AND NEEDS FOR RISK ASSESSMENT OF HAZARDOUS MATERIALS SHIPMENTS BY TRUCKS

Antoine G. Hobeika and Sigon Kim

ABSTRACT

Risk assessment of hazardous materials movement by trucks is data intensive, and its analysis depends on several data sources and on the quality of the input data. This paper reviews the sources of available data at both federal and state levels for major components of risk assessment. It evaluates the adequacy as well as the structural problems associated with accident, incident and exposure databases. Particular emphasis is placed on accident and incident databases. The differences and similarities in risk assessment results obtained using federal and state data are highlighted. Pennsylvania and Missouri were used as case studies. Also, the differences in the state data available for California, Illinois, and Michigan are discussed. These comparisons show the impact of utilizing national default values for truck accident rates and the probability of hazardous materials releases in performing routing analyses.

The paper concludes by looking at the data needs for conducting hazardous materials truck safety research and the databases that best meet those needs. The role of technological advances in easing the burden of data collection and dissemination is discussed, including particular technologies, such as Geographic Information Systems (GIS's), which are being adopted by most state departments of transportation, and Automatic Vehicle Identification (AVI), which is being considered by several truck companies.

INTRODUCTION

Virtually all highway shipments of hazardous materials are carried by truck, with more than 400,000 trucks regularly transporting hazardous materials (hazmats) [1]. It is inevitable that when these hazmats are shipped, accidents will occur that result in releases that are capable of causing damage to people, property and the environment. These accidents invariably receive widespread attention. In recognition of the potential disasters associated with the occurrence of hazmat releases, several studies that deal with hazmat truck safety have been conducted at state and federal levels. However, the achievements of these studies have been constrained by the limited type of data available for hazmat truck safety research. Most researchers agree that studies will improve if the relevant hazmat information becomes available in the future.

The encouraging news is that several states are targeting the data needs for truck safety analysis, including trucks that transport hazardous materials. The recent special report by the Transportation Research Board, "Data Requirements for Monitoring Truck Safety" [2], has addressed these concerns, and has recommended several action plans to remedy the situation. Yet the emphasis is still on truck safety in general, with little consideration of hazmat truck safety.

The objective of this paper is to examine the reliability as well as the problems associated with using existing hazmat truck databases for risk assessment and to suggest some strategies that should be adopted by state and federal governments in addressing them.

DATA NEEDS FOR RISK ANALYSIS OF HAZMAT TRUCK MOVEMENT

Risk assessment of hazardous materials movement is generally determined by multiplying the probability of an accident by its consequences. The probability of a hazmat truck accident that results in a release, usually referred to as an incident, is derived from accident/incident data and from truck exposure data. The exposure data records the volume of hazmat movements on the highway network. The consequence data provide information on the surrounding population, property and environment that could be impacted by a hazmat truck release.

Accident databases contain reports of traffic accidents obtained from police reports, motorists or motor carrier reports, or independent follow-up investigations. Each record in an accident database documents the characteristics of a particular accident and/or a particular accident-involved vehicle. The accident databases of interest to this study are those that contain data on hazmat truck accidents. Also of interest are incident databases which contain reports of occurrences where a hazmat was unintentionally released during its transportation by highway. The existing data sources that concern traffic accidents involving hazardous materials are shown in table 1. Type, size and comments on each database including the agency that collects it are described.

Exposure databases require information about opportunities for accidents/incidents to occur, such as number of hazmat shipments, tons of hazmat shipped, or vehicle-miles of hazmat shipped. The existing sources of hazmat exposure data are also shown in table 1. It is noted that exposure data that closely correspond to the available accident or incident data are seldom available. In analyzing hazmat truck accidents, it is often necessary to force a fit between disparate sources of data, such as the FHWA Motor Carrier Accident Reports and the Census Bureau's Truck Inventory and Use Survey, to determine truck accident rates. Mismatches between accident, incident, and exposure data restrict the ability to perform valid research related to hazmat transportation safety.

The accident consequence data involve the number, quantity, and value of people,

Table 1. Summary of existing accident, incident, and exposure databases

Data base/agency	Type of data base	No. of records	Hazardous materials	Related Factors	Comments
ACCIDENT DATA BASES					
FARS-Fatal Accident Reporting System (USDOT/NHTSA)	All fatal traffic accidents in U.S.	40,000-50,000 accidents per year (1976-present) Approximately 120-150 accidents per year involve hazardous materials	Presence or absence of hazardous cargo (no indication of whether hazardous cargo was released)	Truck type Other vehicles involved Accident type and manner of collision Accident severity Type of roadway location Environmental conditions Travel Speed First harmful event Most harmful event Fire occurrence	Virtually complete reporting of fatal accidents Data are based on police reports and other independent sources No corresponding exposure data
NASS-National Accident Sampling System (USDOT/ NHTSA)	Accident sample drawn from 35-50 representative Primary Sampling Units (PSUs)	Approximately 9,000 accidents per year (1979-1986) Approximately 75 accidents per year involve hazardous materials	Presence or absence of hazardous cargo (no indication of whether hazardous cargo was released)	Truck type Other vehicles involved Accident type and manner of collision Accident severity Type of roadway location Environmental conditions Travel Speed First harmful event Most harmful event Fire occurrence	Data are based on police reports and independent investigating PSU teams Data for truck accidents tend to be incomplete No corresponding exposure data No data on trucks for 1987 and later years
FHWA Motor Carrier Accident Reports (USDOT/FHWA/OMC)	Accidents involving vehicles of regulated interstate motor carriers	Approximately 30,000-40,000 accidents per year (1973-present)	Presence or absence of hazardous cargo Principal type of cargo Occurrence of hazardous material spillage	Truck type Other vehicles involved Accident type and manner of collision Accident severity Highway type and No. of lanes Environmental conditions Driver condition Fire/explosion occurrence	Restriction of data base to regulated interstate carriers creates a sample that is not nationally representative Self-reported data from carriers are not verified from independent sources FHWA estimates 20% to 40% unreported accidents No corresponding exposure data

Table 1. Summary of existing accident, incident, and exposure databases. (continued)

Data base/agency	Type of data base	No. of records	Hazardous materials factors	Related factors	Comments
ACCIDENT DATA BASES (Concluded)					
State traffic accident records system	Accident data assembled from police and motorist report forms	Over 6 million per year in all 50 states	15 states identify presence of hazardous material in accident-involved vehicles. Only Louisiana, Missouri, and Wyoming identify whether or not hazardous materials were released	Truck type Other vehicles involved Accident type and manner of collision Accident severity Type of roadway location Environmental conditions Travel Speed First harmful event Contributing circumstances	Different data format for each state Many accidents not reported Accident reporting thresholds vary
INCIDENT DATA BASES					
Hazardous Materials Incident Reports (USDOT/RSPA/OMHT)	Incidents involving unintentional release of hazardous materials	7,900 incidents per year (1971-present) About 10% of releases are due to traffic accidents	Type of hazardous materials involved Quantity released Type of container and packaging Nature of packaging failure	Type of vehicle or facility Persons injured or killed Property damage	Incidents and accidents are clearly underreported Nontransportation-related incidents are included (e.g., truck terminals, loading docks, etc.) Self-reported data from carriers are not verified from independent sources
EPA Spill Reports	Incidents involving unintentional release of hazardous materials		Verbal description of nature of emergency, type of material spilled and volume spilled	Location Type of source (motor vehicle/other) Nature of response	Many nontransportation-related releases are included Based on self-reported data from shippers, carriers, or owners Computerized only in some EPA regions
State spill reporting systems	Incidents involving unintentional release of hazardous materials		Type of hazardous materials involved Nature of response action Nature of cleanup action	Location Persons injured or killed Property damage	Systems of this type are operated by environmental or transportation agencies in some states
Canadian data	Incidents involving unintentional release of hazardous materials	Approximately 500 incidents per year	Type of hazardous materials involved Quantity released	Persons injured or killed Property damage	Nontransportaion-related incidents are included (e.g., truck terminals, loading docks, etc.) Self-reported data from carriers are not verified from independent sources

Table 1. Summary of existing accident, incident, and exposure databases. (continued)

Data base/agency	Type of data base	No. of records	Hazardous materials factors	Related factors	Comments
EXPOSURE DATA BASES					
TIUS-Truck Inventory and Use Survey (Bureau of the Census)	Survey of a sample of truck owners in all 50 states	Approximately 84,000 truck records in 1982 survey	Percentage of time the truck was used to haul hazardous materials Type of hazardous materials hauled	Truck miles per year Percentage of milage in home State Truck size and characteristics Operator class Range of operation	Conducted every 5 years (1977 and 1982) 1982 TIUS has smaller sample size than 1977 TIUS Many incomplete results, especially at State level
CTS-Commodity Transportation Survey (Bureau of the Census)	Survey of Transportation modes used by a specific sample of companies to ship specific commodities	Approximately 16,000 records in 1977 survey	Type of commodity shipped	Mode of transport Weight of shipment Origin region Destination region	Multimodal data base includes highway, rail, air and water Data base can be used to determine percentage of particular hazardous materials shipped by particular modes Data base is limited to particular commodities It is not always possible to identify hazardous materials shipments in the data base Only shipments from manufacturer to first destination are included Responses are voluntary; approximately 20% response rate may introduce biases
FHWA Motor Carrier Census (USDOT/ FHWA/OMC)	Census of operations by individual motor carriers	Approximately 250,000 motor carrier records	Type of hazardous materials carried Container type used for each USDOT hazardous material class	Home State States served Carrier classification Types of commodities carried Miles operated Number of drivers Number of trucks, tractors and trailers	
Canadian Data	Survey of a sample of specific shipments	Approximately 8,000 shipment records in 1984 survey of for-hire trucking	Type of hazardous materials carried Quantity of hazardous materials carried	Distance traveled Revenue received	Includes separate surveys of for-hire and private trucking Does not include local shipments (under 25 km) or transborder shipments to/from the U.S.

Source: Harwood, et al, 1990[6]

property and sensitive areas exposed to a hazmat release. Most previous studies have used the number of people and the value of property as the measure of consequence for hazmat risk analysis. For example, HAZ-TRANS [9] considers only the number of people in its consequence calculation, and the FHWA model [8] considers only the number of people and the quantity of property. Very few models have considered the environmental and special facility consequences in conducting risk analyses [7]. One major reason is that the collection of site-specific consequence data is laborious, time consuming, and expensive. Besides, the extent of the data needed depends on the impact area created by the release of each hazmat type.

The three components—incidents, exposure, and consequence—are equally important in conducting a meaningful risk analysis. The present databases for these components do not provide sufficient information to allow such an analysis. To support this argument and for the sake of brevity, this paper focuses on the adequacy and structural problems of accident and incident databases.

OVERVIEW OF EXISTING ACCIDENT/INCIDENT DATABASES

From table 1, the main databases are the Research and Special Programs Administration's (RSPA) Hazardous Material Incident Reports (HMIR), the Bureau of Motor Carrier Safety's (BMCS) truck accident database and the State Traffic Accident Records System (STARS). To better understand the federal databases, their reporting requirements are first examined. Then, the regional and state differences in the HMIR database are analyzed to point out the state peculiarities in hazmat incidents. Also, the feasibility of using national default values for risk analyses at state level are covered. The differences between the federal databases for the state of Pennsylvania are analyzed, and then compared with the results of the Pennsylvania Department of Transportation (Penn. DOT) accident database. Finally, the conclusions derived from reviewing the existing databases are made at the end of this section.

Reporting Requirements For HMIR and BMCS Databases

According to RSPA, all incidents related to hazardous materials transportation must be reported in writing within fifteen days of the date of discovery of the incident. The term "incident" refers to an unintentional release of hazardous materials from a package (or tank) or any discharge of hazardous waste during transportation (including loading, unloading or temporary storage) [CFR 49 Part 171.17] [4]. Starting in 1981, there were some exceptions to the regulation that incidents involving small and unintentional releases of consumer commodities need not be reported, such as battery acid, alkali, paint, and paint-related materials.

In addition to the above requirements, immediate telephone notification is required for incidents that involve hazardous materials resulting in:

1. Fatality or injury requiring hospitalization

2. Property damage exceeding $50,000
3. Fire, breakage, spillage or suspected contamination involving the shipping of radioactive material and/or etiologic agents (microorganism or its toxin which may cause human disease)
4. A continuing danger to life at the scene of the incident

The above incidents must be reported if the incident occurs during the course of the transportation of hazardous materials and the result is directly attributable to hazardous materials spillage.

BMCS accident data contain descriptive data of accidents that involve motor carriers and are reported to the Federal Highway Administration (FHWA). This database contains reports of incidents resulting in:

1. A fatality or injury
2. Total damage to property exceeding $4,400

The following accidents need not be reported:

1. An occurrence involving only boarding and alighting from a stationary motor vehicle
2. An occurrence involving only the loading or unloading of cargo
3. An occurrence in the course of farm-to-market agricultural transportation by motor carriers
4. An occurrence in the course of the operation of a passenger car by a motor carrier that is not transporting hazmats

The reporting requirement, especially the minimum damage requirement, has been changed several times. Between 1973 and 1985, the minimum damage requirement was $2,000. This was changed to $4,200 in January 1986 and remained so until March 1987. In March 1987, the minimum damage requirement was again changed to $4,400.

In addition to the characteristics of accidents, the BMCS database contains information as to whether a truck carrying hazardous material was involved and whether or not a hazardous material release took place. However, this database has information only about the accidents of trucks involved in interstate transportation.

The two databases mentioned above are federally operated and rely on voluntary reporting of the incidents/accidents.

Distribution of Hazmat Incidents by Region

The Midwest Research Institute (MRI) carried out a study that was designed to examine the distirbution of hazmat incidents by region of the United States. The study employed five years of data, from 1981-1895 [6]. The results are shown in table 2, and the regions are illustrated in figure 1. Portions of this analysis used the

Table 2. Distribution of On-Highway Hazmat Incidents by Region.

Region	All Reported Incidents* Total No.	%	Incident Caused By Traffic Accidents (A) No.	%	Hazardous Commodity Flows By Trucks** (B)	Hazmat Truck Incident Rates (A/B)
New England	309	(2.30)	44	(3.0)	15,641	0.0028
Middle Atlantic	2,164	(16.0)	160	(11.0)	66,657	0.0024
South Atlantic	2,068	(15.3)	219	(15.1)	49,212	0.0044
East North Central	2,617	(19.4)	177	(12.2)	115680	0.0015
East South Central	1,163	(8.6)	110	(7.6)	14578	0.0075
West North Central	1,785	(13.2)	166	(11.4)	26609	0.0062
West South Central	1,308	(9.7)	225	(15.5)	173,219	0.0013
Pacific Northwest	477	(3.5)	108	(7.4)	21245	0.0051
Pacific Southwest	1,575	(11.7)	235	(16.2)	77541	0.0030
Alaska and Hawaii	18	(0.1)	7	(0.5)	3154	0.0020
TOTAL	13,484		1,451		566,160	

Sources:

* Harwood, et al, 1990[6]. These results are based on 5 years of data (1981-1985).

** Office of Technology Assessment[5]. These values are based on 1977 survey and recorded in thousands of tons.

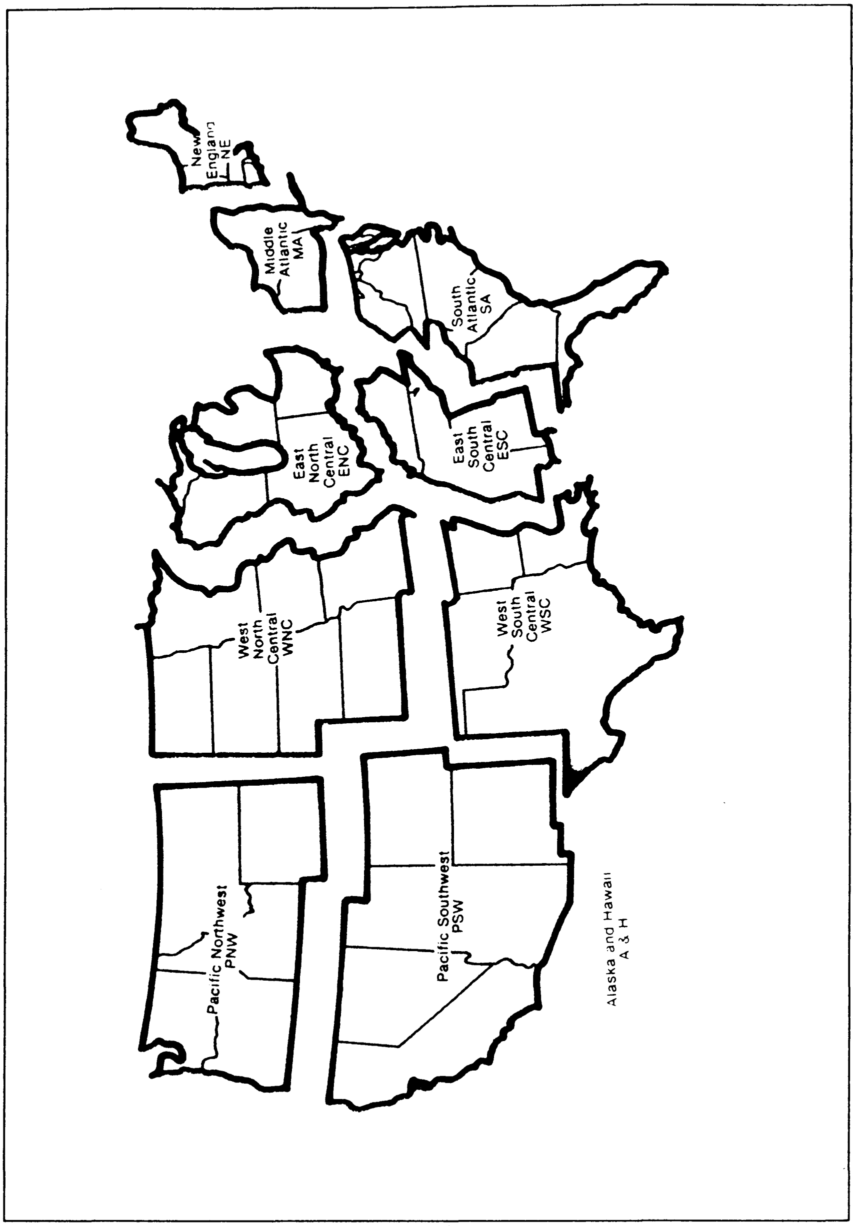


Figure 1. Regions of the United States used in data base analysis[5].

same regions adopted by the Office of Technology Assessment study (OTA) [5]. The hazmat commodity flow data reported in the OTA study for these regions are introduced into the MRI table so that a comparison of incidents among the regions can be made. The table assumes that vehicle miles of travel are proportional to tons carried. Although the flow data do not cover the same time period as the incidents, the rough comparison shows that the incident rates are dissimilar among the regions.

Distribution of Hazmat Incidents by State

Based on the same five years of HMIR data, MRI [6] also analyzed the distribution of hazmat incidents by state as shown in table 3. Only the ten highest states are presented. It was not possible to determine the accident rates for these states since the exposure data were not available for them. However, it is hard to believe that the number of hazmat incidents in Missouri is larger than the number in New York.

Based on the distribution of hazmat incidents by region and state, the HMIR database shows inconsistencies and, possibly, underreporting of incidents. This also raises the question of whether this database should be used to develop national default values for application in risk modeling.

Table 3. Distribution of On-Highway Hazmat Incidents by State for 10 Highest States, 1981-1985 (Source: Harwood et al., 1990 [6])

	All Reported Incidents			
	Total		Incidents Caused by Traffic Accidents	
State	No.	%	No.	%
Pennsylvania	1,340	9.9	73	5.0
California	763	5.7	62	4.3
Ohio	749	5.6	93	6.4
Illinois	742	5.5	45	3.1
Missouri	654	4.9	105	7.2
Texas	589	4.4	58	4.0
North Carolina	555	4.1	39	2.7
New York	553	4.1	35	2.4
Tennessee	481	3.6	38	2.6
Indiana	434	3.2	27	1.9
Others	6,624	49.1	876	60.4
TOTAL	13,484		1,451	

A Critical Look at Using National Default Values

National values obtained from national databases, such as HMIR, are used in risk assessment models simply because the relevant data are not available at the state level. These values include the probability of a hazmat release, the truck accident rates by area and highway type, and truck accident characteristics as a replacement for hazmat truck accident characteristics. Each of these items is briefly discussed.

The Probability of a Hazmat Release. Only thirteen states have police-reporting accident forms that clearly distinguish which accident-involved vehicles were carrying hazmats [6]. Also, in only three states, Louisiana, Missouri and Wyoming, is it possible to determine whether a hazmat release resulted from an accident. The Missouri hazmat truck accident data is used to compare states' own values and HMIR national default values for the probability of hazmat releases. Table 4 presents the probability of a hazmat release by highway class based on hazmat accidents from 1985 to 1986 in Missouri.

Table 4. Probability of a Hazmat Release in Missouri by Highway Class, 1985-1986 (Source: Harwood, et al., 1990 [6])

Accidents Involving Hazmat-Carrying Vehicles

Highway Class	Combined No.	Combined %	No Release No.	No Release %	Hazmat Release No.	Hazmat Release %	Release Probability %
Interstate	96	23.1	82	22.6	14	26.4	14.6
U.S. or State Route	145	34.9	121	33.3	24	45.3	16.6
Supplementary or County Road	55	13.2	46	12.7	9	17.0	16.4
City Street	118	28.4	113	31.1	5	9.4	4.2
Other	2	0.5	1	0.3	1	1.9	50.0
TOTAL	416		363		53		12.7

Table 5 presents examples of typical truck release rates developed by MRI [6], using data from California, Illinois, and Michigan on the probability of a release given an accident. A big difference is shown in comparing the probability of a hazmat release between Missouri values and the national default values. Even though exact comparisons cannot be made due to the different categories of highway class, the Missouri values are almost twice the national default values if the Missouri city street and other highway classes are excluded. This result leads to the conclusion that it is not reasonable to replace the probability of hazmat release value in Missouri by national default values.

Table 5. National Default Release Probability for Use in Hazmat Routing Analyses
Source: Harwood, et al., 1990 [6]

Area Type	Highway Type	Probability of Release Given an Accident (%)
Rural	Two-Lane	8.6
Rural	Multilane Undivided	8.1
Rural	Multilane Divided	8.2
Rural	Freeway	9.0
Urban	Two-Lane	6.9
Urban	Multilane Undivided	5.5
Urban	Multilane Divided	6.2
Urban	One-Way Street	5.6
Urban	Freeway	6.2

Truck Accident Rates. Table 6 presents the all-truck accident rates for three states—California, Illinois, and Michigan—using the BMCS federal databases. It also shows the weighted average values, adopted for national default values by FHWA [6] based on the three states' data. The rates in some states for a particular roadway type and area type are twice that of the weighted average and in some other cases the national default value is much greater than the state value. In other words, the national default values should not be used as a replacement for the actual state values.

National Default Values for All Trucks vs. Hazmat Trucks. National default values for all-truck accident rates have often been used as surrogates for hazmat-truck accident rates. Table 6 is a good example of that. The use of such a surrogate assumes that hazmat-truck accident characteristics are similar to all-truck accident characteristics and that hazmat-truck movements are a fixed percentage of all-truck movements on all types of roadways. The validity of these assumptions has been questioned recently by several researchers, notably Buyco and Saccomanno [11], and Hubert et al. [12]. Even if these assumptions were valid, risk assessment analysis at the local level, where the highway networks are primarily of a single type, would be solely dependent on consequence values. The use of national default values for all rural roads and the use of such values for all segments of the interstate system tends to give great weight to consequence measures in routing decisions. In other words, the minimum risk route for a hazmat shipment is the one that avoids high population density, employment centers, and critical environmental areas. This almost eliminates the need for conducting risk assessment analyses.

At this juncture, it is important to note that each state has unique hazmat-truck shipment characteristics, and that state derived values for accidents/incidents should be used for risk analysis. The next question to be answered is: What data source provides

Table 6. Truck accident rates by State and combined.

Highway Class		Truck accident rate* (accidents per million veh-mi)			
Area type	Roadway type	California	Illinois	Michigan	Weighted average[a]
Rural	Two-lane	1.73	3.13	2.22	2.19
Rural	Multilane undivided	5.44	2.13	9.50	4.49
Rural	Multilane divided	1.23	4.80	5.66	2.15
Rural	Freeway	0.53	0.46	1.18	0.64
Urban	Two-lane	4.23	11.10	10.93	8.66
Urban	Multilane undivided	13.02	17.05	10.37	13.92
Urban	Multilane divided	3.50	14.80	10.60	12.47
Urban	One-way Street	6.60	26.36	8.08	9.70
Urban	Freeway	1.59	5.82	2.80	2.18

[a] Weighted by veh-mi of truck travel.

* Source: Harwood, et al, 1990[6]

the best state-derived values for accidents/incidents? The next section addresses this question by comparing the federal databases, HMIR and BMCS, with the state accident record system of the commonwealth of Pennsylvania.

Analysis of Hazmat Accident/Incident Databases for Pennsylvania

HMIR Data Characteristics for Pennsylvania. The hazardous material incident data for the state of Pennsylvania for the years 1983-1987 were obtained from the HMIR database and analyzed. The HMIR database has reports of all unintentional hazmat releases, whether they took place during highway shipment of hazardous materials or in other locations. Thus, the data had to be separated into "on-highway" and "off-highway" locations. This study focuses on on-highway incidents.

The HMIR database contains the types of hazmats released by hazard class and also by name of the chemical. There are some surprising outcomes in the study of the amounts of spills in individual incidents. These spills involved hazardous materials in the solid state (measured in pounds) or in the liquid state (measured in gallons). In 386 incidents out of 1,136 (more than one-third), the amount of the spill was zero, and in 305 incidents, the spill was one gallon or one pound. The amount of spill exceeded 10 gallons or 10 pounds in only 200 incidents. These results are displayed in the form of a bar chart in figure 2. The figure shows both types of spills. It is known that the HMIR database reports only those incidents in which a spill has taken place. However, we find that 80% of the incidents have insignificant

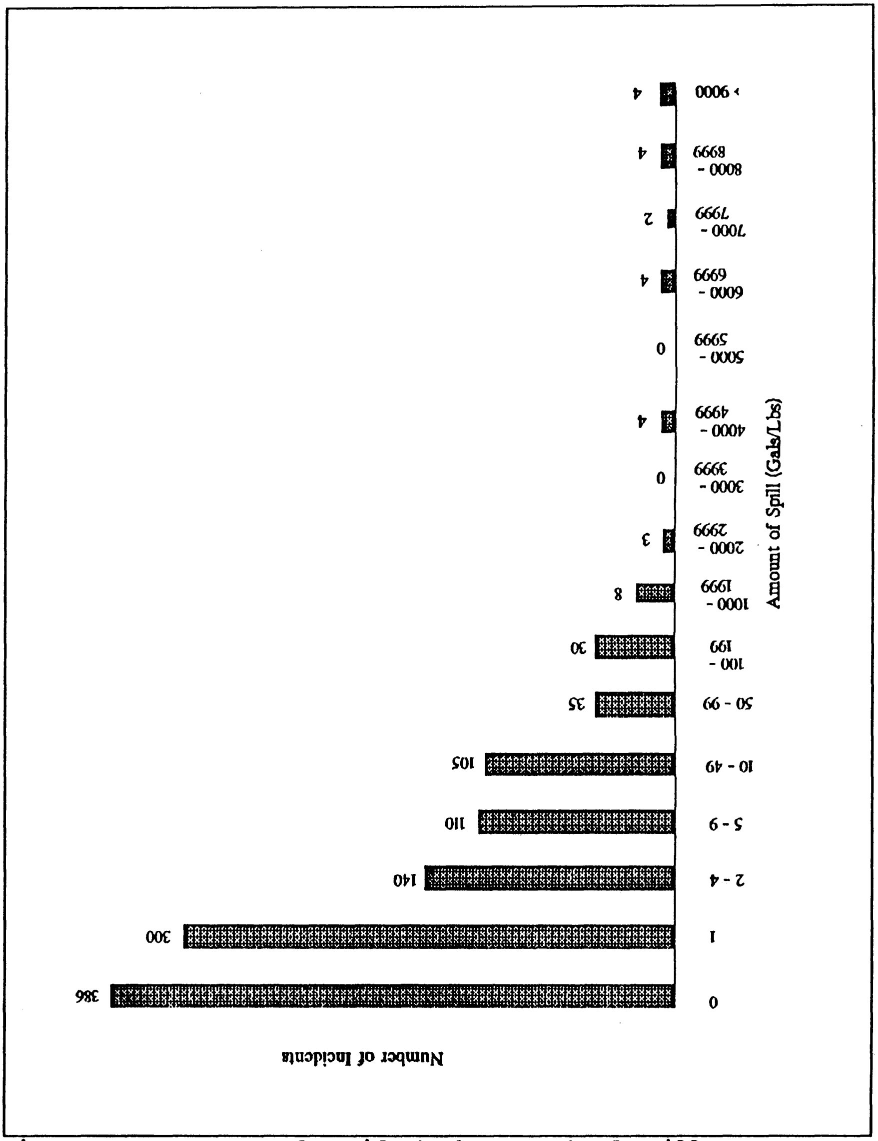


Figure 2. Frequency of Incidents by Amount of Spill

spills. The fact that more than one-third of the incidents show nothing spilled raises questions of underreporting of data.

Table 7 shows a summary of consequences of hazmat incidents reported to HMIR during the period 1983-1987. A total of three deaths occurred on Pennsylvania highways during this period, all of them as a result of traffic accidents involving hazardous material spillage. The average number of deaths per incident is 0.0026. The number of injuries is 17, and the average is 0.015 injuries per incident. The average property damage is $2,170.

Table 7. Summary of Consequences of Hazmat Incidents* in Pennsylvania—HMIR Data, 1983-1987 (Source: Hobeika et al., 1990 [10])

	Number of Incidents	Incidents Caused by Traffic Accidents	Incidents Due to Other Causes**
Number of Incidents	1136	62	1074
Number of Fatalities	3	3	0
Fatalities/Incident	0.0026	0.048	----
Number of Injuries	17	1	16
Injuries/Incident	0.015	0.016	0.015
Total Property Damage ($)	2,463,290	1,690,242	773,048
Property Damage/Incident ($)	2,170	27,260	720

*On-highway incidents only
**Valve or fitting failure, body or tank failure, cargo shifting, etc.

BMCS Data for Pennsylvania. The accident data obtained from BMCS for the state of Pennsylvania for the years 1986-1987 were also analyzed. As mentioned earlier, the BMCS database has reports of truck accidents and also has information as to whether a hazmat carrying truck was involved and whether a release occurred during the accident.

A total of 318 deaths and 3,751 injuries occurred in all BMCS-reported truck accidents in Pennsylvania for the years 1986-1987. Of these, the number of deaths and injuries that occurred due to accidents involving hazmat-carrying trucks was 24 and 178, respectively. A further distribution of these consequences is shown in table 8. Note that accidents involving a hazmat release are likely to cause more deaths than those that do not involve release of a hazmat.

Penn DOT Traffic Accident Data Involving Hazmat. The traffic accident data of Pennsylvania for the years 1986-1987 were provided by the Bureau of

Table 8. Summary of Consequences of BMCS Reported Truck Accidents in Pennsylvania (1986-1987)

	All Truck Accidents	Accidents Involving Hazmat Carrying Trucks		
		Combined	No Release	Hazmat Release
Number of Accidents	3,631	168	140	28
Number of Fatalities	318	24	17	7
Fatalities per Accident	0.088	0.143	0.121	0.25
Number of Injuries	3,731	178	158	20
Injuries per Accident	1.033	1.06	1.129	0.714
Total Property Damage ($)	11,836,734	539,575	470,275	69,300
Property Damage Per Accident ($)	2,360	3,212	3,360	2,475

Source: Hobeika, et al., 1990 [10]

Accident Analysis-Penn. DOT. These data are based on police accident records. Almost all accidents have to be reported to the police and are then recorded in the Penn. DOT accident data. However, this database has no information on whether or not a hazardous material release took place. The only information relevant to hazardous material analysis is whether or not a hazardous material substance was involved in the accident. In the following sections, the above databases are analyzed, and the hazmat accidents/ incidents are distributed based on their consequences.

Table 9 presents a summary of consequences of accidents involving hazardous substances in Pennsylvania. A total of 570 hazmat accidents occurred, resulting in 33 fatalities and 493 injuries (i.e., 0.058 fatalities/accident and 0.865 injuries/accident).

Comparison of Federal Databases for Pennsylvania. BMCS and HMIR databases are compared to note if there are any differences in the standards for reporting. In order to compare these databases, only incidents caused by vehicular accidents were considered in the HMIR data, whereas in BMCS data only accidents involving the release of hazardous materials were considered.

Table 9. Summary of Consequences of Hazmat Accidents in Pennsyylvania—Penn. DOT Data, 1986-1987 (Source: Hobeika, et al., 1990 [10])

Number of Accidents	570
Number of Fatalities	33
Fatalities per Accident	0.058
Number of Injuries	493
Injuries per Accident	0.865

There were 28 incidents due to vehicular accidents in the HMIR data and 28 accidents resulting in hazardous materials release according to BMCS data for Pennsylvania for 1986-1987. According to BMCS, there were seven fatalities and 24 injuries; whereas, according to HMIR data, there was only one fatality and no injuries. Although the reporting requirements for fatalities and injuries differ under HMIR and BMCS, the above comparison gives an idea of the extent of the difference. The above incidents were traced and compared with one another based on the location, date and characteristics of accidents/incidents. When compared, only 10 of the incidents matched. It is shocking to note the number of incidents that go unreported. Eighteen vehicular accidents that resulted in the release of a hazardous material were not reported to HMIR although they were reportable. Similarly, eighteen vehicular accidents were not reported to BMCS. However, only 10 of those were reportable because of the $4,400 minimum damage requirement. Previously, a similar study was conducted by the Office of Technology Assessment [OTA 1986], and the problem of under-reporting to HMIR and BMCS databases was highlighted.

In the 10 incidents which appear in both the databases, the consequences are very different. HMIR recorded no fatalities or injuries, whereas BMCS recorded seven injuries. It must be noted, however, that both of these databases are based on voluntary reporting, so the chance of under-reporting is high. The above results are summarized in table 10.

Table 10. Comparison of BMCS and HMIR Data for Pennsylvania (Source: Hobeika et al., 1990 [10])

	BMCS (1986-1987)	HMIR (1986-1987)
Number of Accidents/Incidents	28	28
Number of Fatalities	7	1
Fatalities per Accident/Incident	0.25	0.035
Number of Injuries	20	---
Injuries per Accident/Incident	0.714	---

Comparison of Federal and State Databases For Pennsylvania. BMCS and Penn. DOT data are compared to see if differences and/or similarities between the federal and state databases exist. Penn. DOT data are more complete than the BMCS data because Penn. DOT has information on accidents occurring during both interstate and intrastate transportation. The accidents involving hazardous substances in Penn. DOT data are compared with the accidents involving hazardous material trucks in BMCS data. The comparison is shown in table 11. From 1986 to 1987, the number of accidents involving hazardous substances, according to Penn. DOT data, is 570. This is a much larger figure than the 168 accidents involving hazardous material trucks reported to BMCS during the same period. The number of fatalities according to Penn. DOT data is 33 and the number of injuries is 493. These figures are far higher than the corresponding figures shown by the BMCS data. These differences clearly show the extent of missing or unreported data in the BMCS database, because BMCS only has a record of truck accidents involved in interstate transportation.

Table 11. Comparison of BMCS and Penn. DOT Data for Pennsylvania (Source: Hobeika, et al., 1990 [10])

	BMCS (1986-1987)	PENN. DOT (1986-1987)
Number of Accidents/Incidents	168	570
Number of Fatalities	24	33
Fatalities per Accident/Incident	0.143	0.058
Number of Injuries	178	493
Injuries per Accident/Incident	1.06	0.865

Conclusions from Pennsylvania Data Comparisons

It is easy to conclude that the state accident record system provides more reliable information on accidents in a state, because it includes both interstate and intrastate accidents. It also gives a better idea about the location of accidents on the highway network. These locations were found to be different in various databases. The locations of high accident segments are important to state agencies that are responsible for providing accident mitigation measures in addition to being a key variable in routing analyses.

Unfortunately, as stated earlier, only 15 states have information about hazmat truck accidents, and only three of them have data that indicate whether a hazmat release has taken place due to an accident. Until all states adopt a uniform truck accident reporting system that provides information on hazmat accidents and hazmat releases, risk analysts will have to depend on federal databases that might give inaccurate results.

THE STATE AND FEDERAL ROLES

Recently, the Transportation Research Board (TRB) [2] studied and recommended that individual states adopt the National Governor's Association's (NGA) recommendations on uniform truck accident reporting and thereby establish uniform truck accident data. The data elements included in the NGA-recommended uniform truck accident reporting procedure are shown in table 12. The recommendations are tailored to all truck transportation safety, with little consideration of hazmat truck safety. The NGA accident record system reports hazmat accidents/incidents but not the quantity of hazmat releases. Only eight states have adopted the NGA recommendations, but more are expected to join soon. Once enough states have joined the system, the federal government could select certain states to create a monitoring system out of their databases. This monitoring system, updated on an ongoing basis, would contain vehicles, roadways, drivers, and accident and exposure files on hazmat truck movements of sufficient detail to enable researchers to conduct meaningful studies in the field of hazmat truck safety.

A similar database to the one recommended above has been developed by the Federal Highway Administration (FHWA) for the purpose of conducting research in the field of highway safety in general. The database is referred to as the Highway Safety Information System (HSIS). It consists of information regarding accidents, vehicles, drivers, traffic and roadway characteristics collected over a three-year period. The records are from five states: Utah, Maine, Michigan, Minnesota, and Illinois.

However, the accident records are not uniform, and none of these state systems report whether accidents resulted in hazmat releases. So the HSIS database was not built with hazmat truck safety in mind. A comparable system to HSIS based on the new NGA uniform truck accident data would be a helpful step towards providing a meaningful tool for hazmat safety research.

THE TECHNOLOGY ROLE

Recent technological advancements in Geographic Information Systems (GIS's) and in Automatic Vehicle Identification (AVI) could be employed to facilitate data collection and dissemination in the field of hazmat truck safety. A GIS is a computerized database management system designed for the capture, storage, retrieval, analysis, and display of spatial data. Most state departments of transportation have or are in the process of implementing a GIS for managing their roadway information. Some states are already capable of displaying accident information stored as attributes of highway segments. Highway segments are represented as polygons, lines or points in a GIS. Attribute data are attached to these lines or arcs that cover roadway, travel, accident, driver and consequence characteristics to name a few. The user can retrieve this information easily and change it over time as conditions dictate. As an example, GIS can play an important role in determining automatically the consequences on various impact areas caused by the release of different hazmats. Otherwise, such calculation could be laborious, especially for a large number of highway segments. An

TABLE 12 SPECIFICATIONS OF THE IDEAL DATA ELEMENTS

Unless otherwise indicated, the specificity is identical to that of the National Governors' Association recommended uniform truck accident reporting procedure (National Governors' Association 1989).

Vehicle Configuration
- Single-unit truck (two axles, six tires)
- Single-unit truck (three or more axles)
- Truck/trailer
- Truck-tractor (bobtail)
- Tractor-semitrailer
- Tractor-double trailer
- Tractor-triple trailer
- Cannot classify

Cargo body style
- Van
- Tank
- Flatbed
- Dump
- Concrete mixer
- Automobile transporter
- Garbage or refuge
- Other

Was hazardous cargo present in the truck?
- Yes
- No

Hazardous cargo class
- Four-digit placard number or name
- One-digit placard number

Was hazardous cargo released?
- Yes
- No

Carrier identification
- U.S. Department of Transportation number
- Interstate Commerce Commission motor carrier number
- State number
- Other number
- None

Driver age

Accident severity
- Number of fatalities
- Number of injured people transported away
- Number of vehicles towed away

Accident events (in order of occurrence)
- Run off road
- Jackknife
- Overturn
- Downhill runaway
- Cargo loss shift
- Fire
- Separation of units
- Collision with pedestrian
- Collision with motor vehicle
- Collision with parked vehicle
- Collision with train
- Collision with pedalcycle
- Collision with animal
- Collision with fixed object

Accident events-continued
- Collision with other object
- Other

Roadway functional class (not in NGA procedure)
- Interstate
- Other principal arterial
- Major arterial
- Major collector
- Minor collector
- Local road or street

Degree of urbanization (not in NGA procedure)
- Rural
- Urban

Trafficway
- Undivided two-way
- Divided, without traffic barriers
- Divided, with traffic barriers
- One-way

Access control
- Unlimited access
- Full control
- Other

Road surface conditions
- Dry
- Wet
- Snow
- Ice
- Sand, mud, dirt, oil
- Other
- Unknown

State

Weather
- No adverse conditions
- Rain
- Sleet or hail
- Snow
- Fog
- Blowing sand, soil,dirt, or snow
- Severe cross wind
- Other
- Unknown

Time of day

Light Conditions
- Daylight
- Dark(not lighted)
- Dark(lighted)
- Dawn
- Dusk
- Unknown

Day of week

Month

Year

Source : TRB Special Report 228, 1990[2] example of GIS in hazmat transportation is shown in figure 3. The figure represents the commercial highway networks for Bethlehem City in the commonwealth of Pennsylvania. The authors, Hobeika and Kim, have developed a tailored micro-computer GIS for hazardous materials risk assessment and routing for Penn. DOT, [10] where Bethlehem City was used as a case study.

AVI is another technology that could benefit hazmat truck safety data, particularly in the exposure area. The technology could identify travel data and vehicle identification automatically. Trucking companies are willing to deploy such technology because it helps in managing their fleets. Although this initiative is just beginning to emerge, it represents a move toward more voluntary regional programs rather than mandatory state or national requirements. Cooperation between state governments, federal governments and industry is needed to achieve uniformity in operations and to support industry in releasing information on hazmat truck travel.

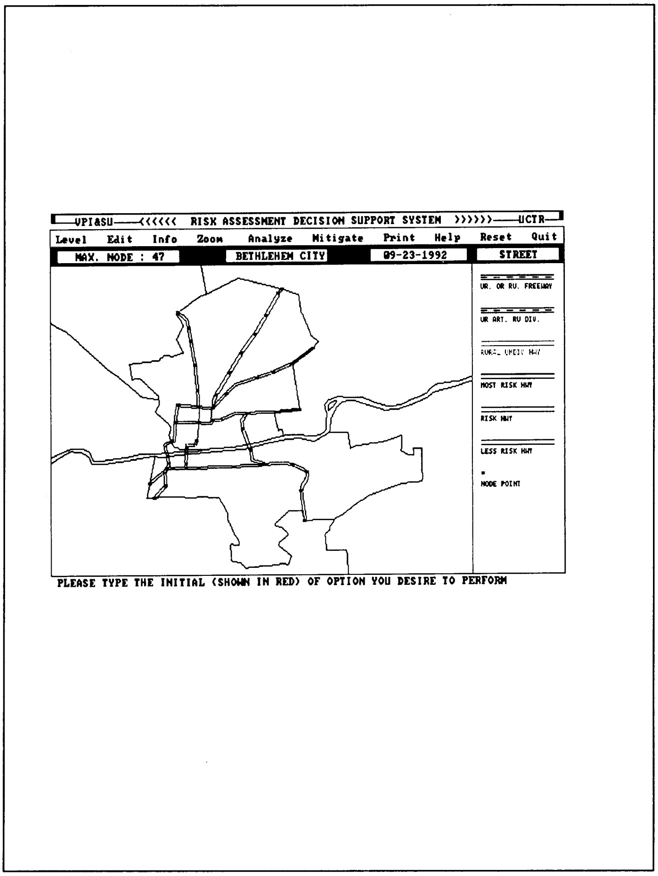


Figure 3. A GIS for Hazmat Risk Assessment Applied to Bethlehem City in Pennsylvania

CONCLUSIONS AND RECOMMENDATIONS

Existing databases for hazmat truck accident/incident and exposure do not provide adequate information for risk assessment of hazmat truck movement. Consequently, routing analysis and mitigation measures are not based on sound inputs of risk values. States have accident record systems that differ from one another. This fact makes nationwide analysis exceedingly difficult. Moreover, a national monitoring system could never be effective due to this nonuniform accident record system among states. The authors recommend that individual states adopt the National Governor's Association procedure for uniform truck accident reporting. A national hazmat truck accident database could then be developed by combining uniform hazmat truck accident data provided directly by individual states over time. This database should be similar to the Highway Safety Information System developed by the Federal Highway Administration. But it should be built with the intention of improving hazmat safety through improved research. Finally, some technologies, such as GIS's and AVI, could be applied to hazmat truck accident data acquisition to help relieve the burden of actual data collection and manipulation.

REFERENCES

[1] National Transportation Safety Board. 1981. "Safety Effectiveness Evaluation - Federal and State Enforcement Efforts in Hazardous Materials Transportation by Trucks." Report No. NTSE-SEE-81-2, February.

[2] Transportation Research Board. 1990. "Data Requirement for Monitoring Truck Safety." Special Report 228, Washington, D. C.

[3] Hobeika, A. G., Sethuraman, R., Kim, S. 1990. "Characteristics of Hazardous Materials Accidents/Incidents in Pennsylvania." Submitted to the Journal of Transportation Science, ORSA, February.

[4] Code of Federal Regulations, Title 49: Transportation, Parts 100 to 177, 1986.

[5] Office of Technology Assessment. 1986. "Transportation of Hazardous Materials." Report No. OTA-SET-304, July.

[6] Harwood, D. W. and Russell, E. R. 1990. "Present Practices of Highway Transportation of Hazardous Materials." Final Report, Midwest Research Institute, May.

[7] Kim, Sigon. 1990. "Development of Risk Assessment Decision Support System (RADSS) for Hazardous Materials Movement." Dissertation submitted to Graduate School of Virginia Polytechnic Institute and State University, August.

[8] U.S. DOT. 1989. "Guidelines for Applying Criteria to Designate Routes for

Transporting Hazardous Materials." Washington, D. C.

[9] Abkowitz, M. D. and Cheng, P. D. M. 1989. "A Bi-Criterion Approach to selecting preferred Truck Routes for Hazardous Materials Shipments." Vanderbilt University.

[10] Hobeika, A. G., Kim, S., Sethuraman, R., Taylor, C., Russell, E. R., and Glickman, T. S. 1991. "Hazardous Materials Movement." Draft final report, Pennsylvania Department of Transportation.

[11] Buyco, C. and Saccomanno, F. 1988. "Analysis of Truck Accident Rates Using Loglinear Models." Canadian Journal of Civil Engineering, Vol.15, No.3, June.

[12] Hubert, P., Pages, P., and Degrange, J. P. 1988. "Regional estimation of the risk involved in the transportation of dangerous materials: Comparison of road transport routes at Lyons." CEPN Report No. 1.

11

UNCERTAINTY IN THE ESTIMATION OF RISKS FOR THE TRANSPORT OF HAZARDOUS MATERIALS

F. F. Saccomanno, A. Stewart and J. H. Shortreed

ABSTRACT

A number of significant advances have taken place in recent years concerning the analysis of risks for the transport of hazardous materials. These advances have been fostered by a better understanding of the risk-analysis process and improved data bases. Nevertheless, much of this work remains plagued by numerous inconsistencies and contradictions, and this in turn has generated a lack of public confidence in the process and its results.

This paper reviews the nature of some of these uncertainties and suggests possible reasons for their existence. Risk component estimates from several studies are reviewed, and ranges in these estimates established. The implication of these uncertainties is discussed with respect to error bounds on the overall risks of transporting hazardous materials by truck and rail.

INTRODUCTION

In recent years, the results of a number of studies concerning hazardous materials transport and the risks associated with it have been reported in the literature. Despite a better understanding of the process, many of these studies have yielded varying, and in some cases, conflicting evidence. Inconsistencies have been observed among the models themselves in terms of predictive risks, as well as between model estimates and observed risks from the available databases (Discussion by Purdy on Saccomanno, Shortreed and Mehta, 1990).

The risks associated with the transport of hazardous materials are characterized by unverifiable, rare events with potentially high consequent damages. As a result, the analysis of these risks is plagued by difficulties of validation, uncertainty of prediction and controversy of application, all of which can give rise to problems of credibility. Decision makers and the public at-large remain unconvinced that the process provides a realistic basis for developing effective safety protocols. Frequently, this has resulted in poorly informed decisions that are more a reaction to unknown fears concerning certain transport risks than a product of an objective risk analysis.

The intent of this paper is to review some of the major sources of uncertainty associated with various components of risk for the transport of hazardous materials, to suggest reasons for this uncertainty and to provide a framework for their consideration. Understanding the nature of these uncertainties is an important prerequisite to informed decision making.

SOURCES OF UNCERTAINTY

As illustrated in figure 1, the risk analysis process requires an estimation of six important components:

1. Probability of accident/incident for a given hazardous material shipment
2. Conditional probability of containment system failure given the prior occurrence of an accident/incident
3. Probabilistic linkage between containment system failure and the likelihood of release for different rates and volumes.
4. Comprehensive analysis of dispersal relationships for different material properties and spill environments
5. Estimation of hazard impact zones for different levels of damage, material properties and spill environments
6. Estimation of risks to population and environment from an incident involving specific hazardous materials at a specific location

Generally, each of these components involves distinctive structural submodels with unique sets of input/output factors. Uncertainties in the development and application of these risk submodels occurs as a result of three features:

1. Structural differences in the models themselves (e.g., a model for statistical analysis vs. estimating directly from available data)
2. Underlying assumptions and/or omissions
3. Jurisdictional differences concerning the validation of model results and their applicability

A number of problems help to illustrate these sources of uncertainty. These may be referred to as problems of control, omission and bias:

1. **Controls:** Controls are placed on accidents for vehicles transporting hazardous materials. These controls are factors which either alone or in combination explain significant variations in accident rates, and include:

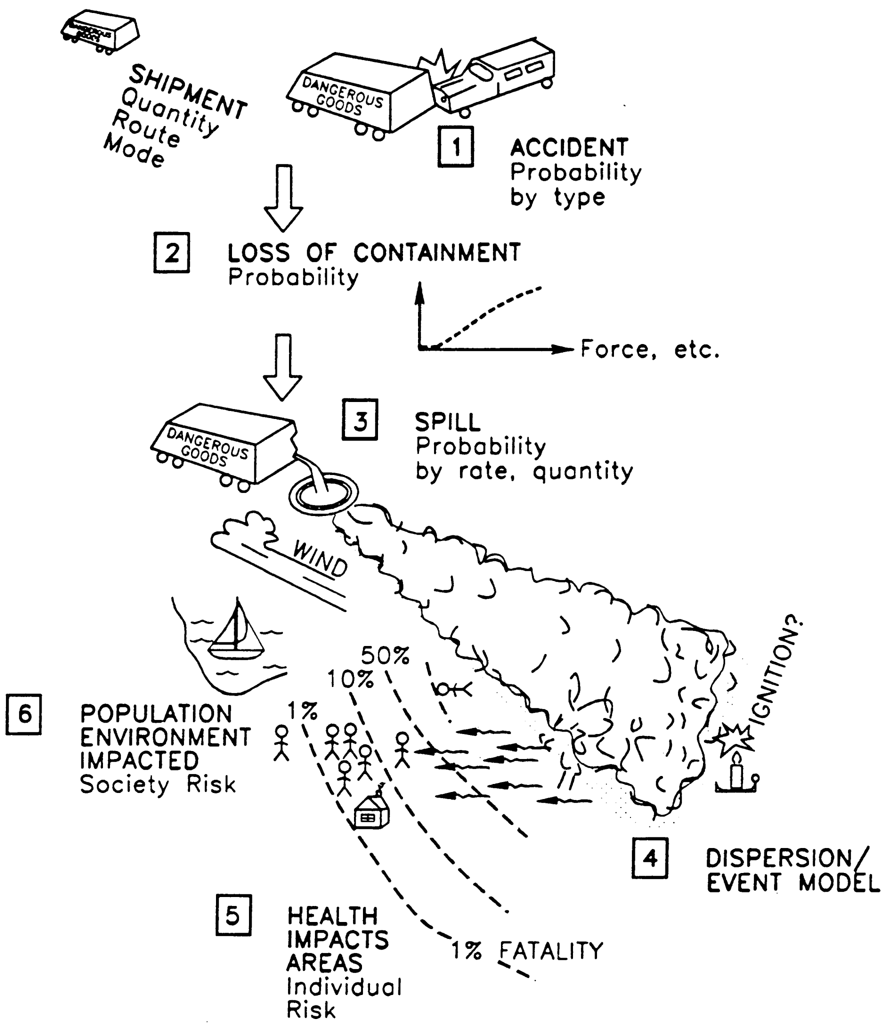


Figure 1 Risk analysis process

road/track geometry, traffic composition, and environment. Many studies concerning the risks of transporting hazardous materials are based on average input values rather than values that reflect the true exposure to controlled accident risk, for example, rail accident rates that fail to account for differences in rolling stock, track and sub-grade quality and alignment. In some studies, rates that have been estimated for one set of controlled conditions are applied to other conditions, without accounting for the appropriate adjustments.

2) **Omission:** Omission of significant factors from the risk model components are made. For example, grade crossing accidents and intersection accidents for rail and road transport, both of which represent a large component of all accidents involving each of these modes, are omitted.

3) **Bias:** Frequently, inputs into the risk analysis process are estimated conservatively, creating a bias that does not reflect reality. Biases in any constituent risk component can produce cumulative biases in the final risk estimates in a worst-case situation. The range of uncertainty associated with the final risk estimate may be well beyond acceptable limits of the true value. The Toronto Area Rail Task Force (1989) contended that some of their estimates were most likely high by a factor of three due to cumulative, conservative assumptions.

Uncertainty may also arise from jurisdictional differences that affect risks and relevant assumptions concerning the application of the process. Frequently, the absence of data in a given jurisdiction (for example, data on releases involving hazardous materials) has necessitated use of data from other jurisdictions for the purpose of calibrating and validating specific risk model components. For example, the Railway Progress Institute (RPI) uses rail accident and release data provided by member companies from all of North America, mixing Canadian and U.S. data from all regions. However, the nature of railway operations and traffic mix in these regions would very likely result in significant differences in derailment rates for rail cars that carry hazardous materials and their corresponding release probabilities.

Confining analysis to one jurisdiction alone would not resolve this problem, since rail accident statistics are subject to technological changes over time that affect the risk-analysis process. Table 1 summarizes Canadian railway accident statistics for the period 1971-81, as reported by Doswell (et.al., 1986). Between 1979 and 1981 a number of regulations applying to hazardous shipments were adopted by railways in Canada in response to the Grange Commission Inquiry into the 1979 Mississauga derailment (Grange, 1980). These regulations center on such measures as retrofitting rolling stock with double-shelf couplers, reinforcing tank heads, replacing friction bearings with roller bearings, and instituting speed controls for trains carrying hazardous materials in certain areas. All of these changes significantly reduced derailments involving hazardous materials and their release. Aggregation of post-1981 rail accident data with earlier data would fail to reflect these changes, and hence over-

Table 1. Canadian Railway statistics (1971-1981)
(All rates per billion metric ton-kilometers)

Year	Accident Rate	Release Rates Total	Major	Minor
1970	8.59	0.99	0.33	0.66
1971	9.73	3.24	2.36	0.88
1972	10.75	2.42	1.61	0.81
1973	12.13	2.70	1.35	1.35
1974	9.83	2.22	0.74	1.48
1975	7.77	1.51	0.22	1.29
1976	9.01	1.68	0.84	0.84
1977	8.61	2.43	0.28	2.15
1978	10.22	2.33	0.72	1.61
1979	10.21	2.39	0.86	1.53
1980	14.88	1.94	0.78	1.16
1981	23.55	0.71	0.24	0.47
AVERAGE	11.27	2.05	0.86	1.19

Percent releasing materials: 18
Percent of releases that are major: 42
Percent of releases that are minor: 58

estimate the likelihood of risks in the same jurisdiction.

In the next section of this paper, various risk component estimates reported in the literature will be discussed. These estimates are presented so that a range of values can be obtained for input into the risk analysis process.

REPORTED RISK COMPONENT ESTIMATES AND RANGES

In this section of the paper, a range of risk component values is presented from the literature. The discussion is arranged into four subsections:

1. Accident Rates: Rail and Truck

2. Release Probabilities in an Accident: Rail and Truck

3. Release Sizes and Damage Distances

4. Site-Specific Risk Estimates

Each section describes the range of component values reported in the literature, and suggests high and low boundary limits for input into risk analysis.

Variations in Accident Rates

Rail Accident Rates. Saccomanno, Shortreed and Higgs (1989) developed a loglinear model of accident rates for derailments based on Canadian Railway Transportation Committee (RTC) data for the years 1980-1986. The results of the derailment model are shown in table 2 for four volume classes and two speed classes. The table shows that volume and speed significantly affected accident rates. The table combines single- and multiple-track configurations and all regions. The rail car accident statistics in table 2 also include collision and crossing-accident rates observed in the data, which could not be explained using the derailment loglinear expressions. In Canada, this represents over 600 train accidents a year, of which 5% involve dangerous goods. Crossing accidents represent 34% of all main track dangerous goods involvements (59% are due to derailments and 7% are due to collisions).

The crossing-accident rates reported in table 2 have been classified by track and speed classes based on adjusted Canadian rail accident data (Coleman and Stewart, 1976). The American rail accident proportions were used as adjustment factors due to the lack of similar relationships developed with Canadian data (Stewart, 1990). Table 2 reflects a significant range of values for rail accident rates, depending on track volume class and average train operating speeds. The highest values were obtained for Low Volume Class 1 with low speed conditions, with a rate of $1.6X10^{-5}$ derailments and $2.45X10^{-7}$ collisions per car-km. These values can be compared to the lower bound estimates of $0.08X10^{-6}$ derailments and $0.01X10^{-8}$ collisions per car-km for low speed, high volume class track (4). Depending on these track and speed control factors, RTC rail accident rates vary by several orders of magnitude. The average rate of $2.15X10^{-8}$ car accidents per car-kilometer reported by Wade (1986) for this data base appears to reflect the lower ranges of values controlled for track class and speed.

Despite the fact that the same source of data is used, such that jurisdictional differences have been controlled, this comparison of rail accident statistics suggests that two sources of inconsistency remain to be accounted for: 1) failure to adjust averages by track and operating environment that explain variations in these rates, and 2) omission of important accident components from the analysis, mainly grade-crossing accidents.

Table 2: Rail Accident Rates per million car-kilometre

	Track Volume Class			
Speed	1[a]	2[b]	3[c]	4[d]
DERAILMENT (Loglinear model estimates)				
0-50 kph	16.1	1.91	.12	.08
>50 kph	9.56	8.65	.06	.076
COLLISIONS (Canadian data)				
0-50 kph	.245	.191	.016	.004
>50 kph	.245	.191	.016	.004
CROSSING ACCIDENTS (Canadian data)				
0-50 kph	.045	.067	.102	.109
>50 kph	.022	.029	.038	.045

a = 0-10^8 ton-miles/year c = 10^9-10^{10} ton-miles/year
b = 10^8-10^9 ton-miles/year d = 10^{10}-10^{11} ton-miles/year

Average Collision and derailment rate 2.15 per billion ton-miles.

Truck Accident Rates. Although many sources of truck accident rates are available in the literature, many do not give rates for all road accident possibilities. For example, Hubert et al. (1988) report only heavy truck accident rates in France that involve some form of personal injury. These accident rates are $2.6\text{X}10^{-7}$ accidents per vehicle kilometer for general large truck traffic and $1.1\text{X}10^{-7}$ accidents per vehicle-kilometer for trucks carrying hazardous materials. These differences between general truck accident rates and rates for hazardous shipments highlight possible sources of error when general truck accident rates are applied to hazardous materials traffic, an approach that has been frequently adopted in the literature.

Both rates reported by Hubert for France appear to be in agreement with large truck accident rates estimated by Buyco and Saccomanno (1988) for the province of Ontario (Tables 3a, 3b). The Ontario rates were adjusted to include truck accidents taking place at or near intersection locations and freeway interchanges. Although truck accident rates were found to depend significantly on truck configuration and loading, the values in table 3a were averaged over all truck types, regardless of configuration. The rates given in 3b are for semitrailer trucks only. Depending on road and traffic controls, the adjusted Ontario rates were found to be in the range of $4.30\text{X}10^{-7}$ to $1.43\text{X}10^{-6}$ per vehicle-kilometer, a range which is slightly lower than the results reported by Hubert. Heavy truck accident rates were found to depend significantly on the type of road, traffic condition and truck type. For example, controlling for semitrailer configurations, the Ontario heavy accident data yielded rates in the range of $1.43X10^{-6}$ per truck-kilometer for a high volume rural highway to $4.67X10^{-7}$ for low volume urban freeways, a range of one order of magnitude for the same jurisdiction.

The Ontario statistics are compared in table 3a to values reported by Harwood and Russell (1989a) based on a study of commercial vehicle accidents in Michigan. These results indicate significant geographic variations that could not be modeled with the adjustment to the Ontario data alone. For example, according to the Michigan data, overturns are an order of magnitude lower on high volume roads than on low volume roads. Collision rates are an order of magnitude higher than those derived for the Ontario data. According to Harwood and Russell, trucks experience fewer collisions than the general population of vehicles but more overturns.

Table 3a: Truck accident rates for Ontario and Michigan (per ten million vehicle-km)

			Ontario* (Adjusted)		Michigan. Commercial Veh.	
ACCIDENT TYPE	% OCCURRING	ROAD TYPE	LOW VOLUME	HIGH VOLUME	LOW VOLUME	HIGH VOLUME
Overturn*	25	Nonfreeway	1.17	3.60	1.15	.25
		Freeway	1.27	2.67	2.13	.21
Collision	67	Nonfreeway	3.13	9.63	13.3	66.9
		Freeway	3.41	7.18	10.7	35.7
Crossing Accident	1	Nonfreeway	.03	.09	.005	.01
		Freeway	0	0	.01	0
Other	7	Nonfreeway	.33	1.02	.02	.74
		Freeway	.36	.75	.23	.26

Table 3b: Aggregate loglinear model results for Ontario, for semi-trailer trucks (per 10 million veh-km)

	Highway link rates*		Model results adjusted for intersection and ramp rates	
	Low Volume	High Volume	Low Volume	High Volume
NonFreeway	4.66	14.3	4.67	14.3
Freeway	5.04	10.6	5.05	10.6

*Estimated by GLIM loglinear analysis Saccomanno and Buyco (1988).

Sparks et al. (1988) estimated large truck accident rates using province of Saskatchewan data. They reported an average accident rate of $7.13X10^{-7}$ per vehicle-kilometer, which is comparable to a rate of $7.6X10^{-7}$ per vehicle-kilometer reported by Harwood and Russell for U.S. interstates and $10.6X10^{-7}$ reported by Buyco and Saccomanno (1988) for high volume Ontario freeways. The 95% confidence interval for the Saskatchewan data represents a range of accident rates from $5.0X10^{-7}$ to $1.1X10^{-6}$ per vehicle-kilometer, an interval that includes both the U.S. interstate highway accident rate and the truck accident rate estimated for Ontario.

Three sources of variation are present in the estimation of large truck accident rates: road/traffic controls, truck/loading type and jurisdictional factors. The accident rates reported for Ontario (table 3a) were used as inputs into subsequent risk analysis. Depending on road and traffic type, high and low estimates can be obtained, i.e., $1.43X10^{-6}$ for high volume nonfreeway links and $4.67X10^{-7}$ for low volume, nonfreeway links.

Release Probabilities in an Accident

Rail Tanker Releases. Since the release of goods during rail transport is relatively rare, there are few sources from which to establish a range for probability of release given an accident. In addition, changes in the rail environment have made pre-1980 data incompatible with post-1980 data. To deal with these limitations, some reports consider all releases of dangerous goods regardless of the type of material involved. Since containment systems vary with type of material in transit, aggregation of materials for the purpose of explaining releases may be subject to significant error.

The results of studies from the United Kingdom, Canada and the United States will be used to illustrate the range of possible values associated with rail tanker releases for hazardous material shipments.

Health and Safety Executive Studies in the UK. Purdy et al. (1988) report release probabilities from the United Kingdom as shown in table 4a. These are not necessarily representative of North American conditions, but can be used to illustrate various jurisdictional differences. Table 4b gives the fault rates per rail car-kilometer, assuming an average 200-kilometer trip for 29 metric tons of chlorine (Cl) and 40 metric tons of liquefied petroleum gas (LPG) per tanker.

Pacific Northwest Laboraties Fault Tree Analysis and Association of American Railroads Results. The earliest application of fault tree analysis to the study of in-transit releases of hazardous materials was carried out by the Pacific Northwest Laboratories in the U.S. (PNW, 1980). Ranges in release "faults" were obtained for different rail tanker systems, depending on specification inputs. The application of fault trees to this process is hampered by complexities in the structure of the various fault trees that represent the release process and difficulties in specification and validation of available data on releases.

Table 4a: Assumed release size and probability per trip (UK)

Release size	Chlorine	LPG
small (1.3kg/s)	0.005/trip	0.029/trip
med. (4.51kg/s)	0.00225	0.00225
large (29te Cl 40te LPG)	0.00025	0.00025

Table 4b: Estimated release size and probability per million car-kilometre (UK)

Release size	Chlorine	LPG
small (1.3kg/s)	.862	3.625
med. (4.51kg/s)	.388	2.812
large (29te Cl 40te LPG)	.0431	.03125

Table 5 shows fault tree values for LPG (PNW, 1980) for various release types. For comparison purposes, the values obtained from Association of American Railroads (AAR, 1986) data for general rail car derailments in the U.S. are also included in Table 5. All values are per rail car-kilometer. Table 5 shows that the fault trees of PNW underestimate tank wall and tank end failures and seem to overestimate all fire-related releases. However, the fire-related releases are highly variable; for example, the AAR data indicate that there are 5.3 fire-related releases per year with a standard deviation of 6.6. The PNW estimate is within the variation exhibited by this release type. The higher values in the AAR data for walls and ends may reflect the less safe conditions for the general rail car population, as compared to rail cars carrying LPG. LPG tankers are generally stronger and less likely to experience a loss of lading during derailment, assuming that all other factors are equal.

AAR derailment statistics for dangerous goods cars can provide data for the entire fleet of dangerous goods cars. To obtain a range of fault rates, the average value and its 95% confidence interval could be used, as shown in table 6, especially for commodities like gasoline which are hauled in various tank cars. These data are for all hazardous commodities transported in the United States.

Table 5: Fault rates per car involvement in accidents (per 10,000 accidents)

Fault Location	PNW*	AAR**
Tank walls	8.06	109.0
Tank ends	.687	18.1
Fire	58.4	11.5
Overall release rate	67.2	138.6

*Pacific Northwest Laboratories

**Association of American Railroads

TABLE 6: Fault probabilistics for tank cars involved in a derailment (AAR (1986)).

Location of Fault	Average	Standard Deviation
Safety Device	0.008	0.003
Other Top Fitting	0.043	0.014
Head	0.011	0.003
Shell	0.015	0.005
Fire Exposure	0.007	0.009
TOTAL:	0.085	0.010

Institute for Risk Research Fault Tree Analysis. The Institute for Risk Research (IRR, 1987) applied fault tree analysis to estimate the probability of release for rail bulk tankers carrying pressure liquefied chlorine gas and LPG. These fault trees were later revised by Saccomanno, Shortreed and Thomson (1990). Both accident and non-accident initiating events were considered.

Aggregate release probabilities were estimated for each road and rail incident and material type. For both chlorine and LPG tankers, two containment system failures were considered: releases from tank shells and releases from valves. Table 7 summarizes the release probabilities estimated from these fault trees as applied to rail bulk shipments of chlorine and LPG. The results of this analysis suggest that approximately 11% of all rail tanker accidents result in a loss of lading, most of which takes place through a minor venting of the relief valve.

Table 7: Accident-induced release probabilities for rail bulk tankers carrying Chlorine and LPG. (rates per 100 tankcar accidents)

Fault Type	Chlorine	LPG
Tank Shell Total	.0110	.02900
Tank Head	.00067	...
Tank Wall	.00995	...
Manway Cover	.00035	...
Tank Valves	.00906*	.00300
Gas Valve	.00165	...
Relief Valve	.00453*	...
Outlet Valve	.00123	...
TOTAL	.03841	.0320

* excludes "normal" releases for pressure relief valve.

Toronto Rail Task Force Releases. An expression was developed by consultants to the Toronto Area Rail Task Force (1988) that relates the probability of a release to the speed of the rail car at the time of the accident, such as:

$$P = 0.013 * V^{1/2}$$

where P is probability of release and V is train speed (mph).

The result of this comparative analysis of release estimates provides ranges in the order of 0.007 to 0.01 per accident for more serious failures to values in the 10% range per accident if minor leakage through valves is considered (IRR).

Truck Tanker Releases. The release percentages for overturns and other hazmat truck accidents in the United States are shown in table 8 (Harwood et al., 1989b). These values do not give an indication of the size of release. The size of release must be determined in terms of the relationship between the size of opening and energy absorption relationships, similar to that suggested by Hubert (1985), or di rectly with reference to release data (Stewart, 1990; Saccomanno, Shortreed and Mehta, 1990). Hubert (1985) gives the probability of tank rupture and hole size in terms of the joules of energy available in each truck accident. He suggests that in France 25% of overturns occur with a perforating object.

Table 8: US HAZMAT releases in an accident.*

ACCIDENT type	Prob of acc. type	Prob of release given accident	Prob of Accident with release	Prob. of release for Gasoline Tankers	Prob. of release for LPG Tankers
overturn	.251	.353	.0886	.112	.0481
collision	.672	.041	.0274	.034	.0149
crossing	.060	.455	.0273	.034	.0148
other	.071	.083	.0059	.007	.0032
TOTAL			.1492	.188	.081

*Harwood et al. (1989b)

Purdy et al. (1989) in the Tsing Yi risk analysis reported an overall release rate of $2X10^{-9}$ per vehicle-kilometer for trucks carrying LPG. This represents a probability of release of approximately 6% in each accident situation (i.e., approximately 0.7 releases per million vehicle-kilometers). This is similar to the 8.1% release rate shown in table 8 for U.S. LPG trucks and the 10% rate reported by Saccomanno, Shortreed and Thomson (1990) from the application of fault trees to LPG truck shipments.

Release Sizes and Damage Distances

The risk component values discussed in this section reflect the hazard areas associated with different material releases for different types of damage. The hazard areas associated with material releases depend on several factors, among which are:

1. Material properties (toxic, flammable, explosive, corrosive)
2. Mechanics of dispersal (heavy gas, liquid)
3. Critical exposure values to sustain given damages
4. Rate and volume of material released
5. Environmental conditions at the site of release
6. Site-specific factors affecting concentration, fluctuations and shielding

Much of the recent work on hazard area analysis has focused on heavy gas dispersion models. These models can be classified into two types: Gaussian models and heavy gas models. The differences in hazard area estimates resulting from these two formulations can be significant.

Distance to damage is expressed in various ways, and since this is a function of analytical relations not always given in the literature, it is difficult to determine high and low values for damage distances. Tables 9 and 10 summarize hazard-area estimates for rail and truck releases from different sources. Some of the major assumptions concerning the size of release and material type have been noted in these tables. The uncertainty of the comparisons and the range of estimates are also illustrated.

Site-Specific Risk Analysis

Information on accident rates, release probabilities, and release sizes and rates can be viewed as being generic in nature. As such, these estimates can be applied to any location on the transportation network, provided that certain controls have been met. These controls reflect factors in the estimation of the risk component inputs that explain variations from the mean values. The final component of the risk analysis process, however, requires information that is location-specific in nature.

Despite their influence on risk, location-specific inputs are often difficult to model precisely. For example, the probability of being indoors or outdoors has an effect on the number of people who may be sheltered from the full impact of a hazardous material incident. Other location-specific inputs relate to the density and distribution of population in the vicinity of a release and various ground features that affect dispersal of damages given a release. The following list gives a number of site-specific variables that could cause differences in the results of risk analyses:

1. Weather conditions: poor conditions reduce the number outdoors
2. Day and night occurrence which reflects inside and outside populations, and work and home populations
3. Distribution of population (i.e., equally distributed or one-sided?)
4. Distribution of population in terms of predominant winds
5. Air temperature: colder air is more dense, therefore gases may rise rather than act as heavier-than-air gases as in summer
6. Surface roughness increases dilution of gas
7. Air stability: a higher degree of turbulence can disperse gas quickly
8. Wind speed determines distance to damage

Much of the inconsistency surrounding the risk analysis process results from differences in these types of location-specific features. In this paper, variations in the assumptions concerning shielding will be addressed specifically.

In the risk analysis of Tsing Yi, Purdy et al. (1988) suggest that the 24-hour average probability of outdoor/indoor populations is .05/.95. They further suggest

Table 9: Property of Releases for Rail Cars.

SOURCE	COMMODITY	RELEASE CHARACTERISTIC	PROBABILITY GIVEN RELEASE	MAXIMUM DISTANCE TO FATALITY(%)(4)		INJURED
Doswell	ALL (1)	Major release - >25% or fire or explosion	.07	NOT GIVEN		
		Minor release - <25% of lading	.10			
Purdy 1988)	CHLORINE	small - 1.3 kg/s		NOT GIVEN		
		medium - 45.1 kg/s				
		catastrophic - 29 tonnes				
	LPG	small - 2.0 kg/s				
		medium - 36 kg/s				
		catastrophic - 40 tonnes				
Wade (1986) (2)		large > 10 kg/s		(?)(4)		
		torch		18 m		
		pool		170 m		
[from Raj and Glickman (1985)]		vapour fire		360 m		
		v cloud expl		1100 m		
		bleve		180 m		
		toxic gas rel.		600 m		
TNO (1988)	flam liquid	$60\ m^3$ [2000m2 pool 3 cm depth]		(?) 27 m		90 m
	liquefied gas	$50x10^3$ kg BLEVE		100 m		500 m
		$100\ m^3$ Pool Fire		84 m		260 m
				(50%)	(1%)	
Stewart (1990) (3)	LPG	$129m^3$ [shell] fb	.09	260 m	350 m	
		$129m^3$ [valve] fb	.50	190 m	250 m	
		$129m^3$ [shell] uvce	.003	50 m	160 m	
		$129m^3$ [valve] uvce	.01	40 m	120 m	
		$129m^3$ [shell] pool	.04	180 m	220 m	
		$129m^3$ [valve] pool	.001	120 m	150 m	
	GAS	$129m^3$ [shell] pool	.08	200 m	260 m	
		$129m^3$ [valve] pool	.42	150 m	190 m	

Notes:
(1) includes all releases.
(2) includes 40ft displacement of railcar in derailment where applicable, major releases based on entire car contents released; torch fire distance is 100 to 200 time hole diameter.
(3) non-fire related releases not included
(4) % of population fatally impacted (?% - not known)

Table 10: Property of Releases For Trucks

SOURCE	COMMODITY	RELEASE SIZES	PROBABILITY GIVEN RELEASE[1]	MAXIMUM DISTANCE TO FATALITY (%)[2]		INJURED
				(100%)	(10%)	
Hubert (1989)	LPG	minor leak [23 kg/s]	.02	17 m	20 m	
		major leak [5 tonnes]	.018	42 m	50 m	
		aerial explosion	.002	25 m	57 m	
	chlorine	low diffusion [1 m3/s]	.49	1700 m		
		normal " [4 m3/s]	.31	200 m		
		" " [8 m3/s]	.20	3500 m		
				(?%)		
TNO (1988)	flam liquid	$43\ m^3$ [1500 m2 min. pool 3 cm depth]		22 m		80 m
	liquefied gas	$20x10^3$ kg BLEVE		80 m		350 m
		$20x10^3$ kg Pool fire		12000 m2		200 m
				(?%)		
Purdy Tsing Yi (1989)	LPG	small (40mm)hole [15kg/s]	.1125	105 m		
		cat rupt/no ign [5 te]	.05	230 m		
		cat rupt/ign [5 te]	.05	96 m		
		cat rupt/bleve [2.5te]	.3375	76 m		
				(50%)	(1%)	
Stewart (1990)	LPG	$43m^3$ [shell] fb	.10	150 m	200 m	
		$43m^3$ [valve] fb	.30	100 m	120 m	
		$43m^3$ [shell] uvce	.004	30 m	110 m	
		$43m^3$ [valve] uvce	.008	20 m	90 m	
		$43m^3$ [shell] pool	.05	100 m	120 m	
		$43m^3$ [valve] pool	.10	80 m	100 m	
	GAS	$43m^3$ [shell] pool	.004	110 m	150 m	
		$43m^3$ [valve] pool	.07	85 m	100 m	

Note:
(1) probability of release by type, given that accidental release has occurred.
(2) % of population who are fatalities (?% - unreported/not known)

that the following shielding related factors be applied to these outdoor and indoor populations:

	Fraction Killed
Heavy Building Damage Explosion	Outdoors = 1.00 Indoors = 0.75
Reparable Building Damage	Outdoors = 0.50 Indoors = 0.25
Flash Fires	Outdoors = 1.00 Indoors = 0.20
Bleve	Outdoors = 1.00 Indoors = 0.20
Pool Fire	Outdoors = 0.50 Indoors = 0.10

Another assumption used by Purdy is that in explosions and fires there are two injuries to one fatality, and in toxic clouds there are ten injuries to one fatality. Glickman and Rosenfield (1984) found in a study of 75 rail accidents that only 0.2% of the population was exposed to harmful effects. This value differs from Purdy by more than one order of magnitude. Glickman and Rosenfield also felt that the shielding factor is highly variable depending on location and population characteristics. This suggests that shielding should be sensitive to people's ability to escape or protect themselves. In the subsequent risk analysis a shielding factor from 1% to 10% is used to estimate the overall risks of transporting hazardous materials by truck and rail.

A computer model originally developed by the IRR (1987), and modified by Stewart (1990) and Van Aerde et al. (1989), was used to estimate the risk of transporting LPG and gasoline on two transportation modes (rail and road), for high and low accident rates and high and low fault rates. The ranges of component inputs for accidents, releases and hazard areas were estimated with reference to reported values from the literature. The combination of input components resulted in sixteen cases which are outlined in table 11. This table also gives the results of the risk analysis in terms of fatality risk per metric ton-kilometer of commodity shipped.

Figure 2 illustrates the ranges of variation in the final risk estimates for different modes and material types. Variations in overall risks are a result of variations in the individual risk components; for example, variations in the accident environment, the occurrence of containment faults and the accompanying release process, the conditions governing the dispersal of contaminants and their damages, and various route-specific conditions. The purpose of figure 2 is to represent the boundaries of uncertainty

Table 11: Variations in overall risk estimates (16 cases)

CASE NO.	MODE	ACCIDENT RATE (/10^7 VEH-KM)	FAULT RATE (P(REL/ACC))	RELEASE SIZE DIST.	COMMODITY	RISK (10^{10} TONNE-KM)
1	RR	High: low vol. low speed derail-160.0 coll.-2.4 (Buyco and Saccomanno, 1988)	Fault Tree DOT 112 railcar 0.00672 (PNW, 1980)	Assumed (note 1)	LPG	11.0
2	RR	Low: high vol. high speed derail-0.60 coll.-0.16	"	"	LPG	0.05
3	RR	High,as case1	"	"	GAS	4.90
4	RR	Low,as case2	"	"	GAS	0.02
5	RR	High,as case1	AAR Tank Car Derailment Data 0.0138 (AAR, 1986)	Assumed (note 2)	LPG	13.0
6	RR	Low, as case2	"	"	LPG	0.06
7	RR	High, as case1	"	"	GAS	5.70
8	RR	Low, as case2	"	"	GAS	0.03
9	Trk.	High,Nfreeway high volume OT- 3.6 C - 9.6 Oth-1.0	Low US Hazmat release percent 0.081 (Harwood et al, 1989)	Transport Canada Release Distribution (note 3)	LPG	1.30
10	Trk.	Low,Nfreeway OT- 1.2 C - 3.1 Oth-0.33	"	"	LPG	0.42
11	Trk.	High,as Case9	"	"	GAS	0.55
12	Trk.	Low,as Case10	"	"	GAS	0.18
13	Trk.	High,as Case9	High US Hazmat release percent 0.188 (Harwood et al, 1989)	TC Release Distribution (note 4)	LPG	5.50
14	Trk.	Low,as Case10	"	"	LPG	1.80
15	Trk.	High,as Case9	"	"	GAS	2.40
16	Trk.	Low,as Case10	"	"	GAS	0.77

See following page for notes.

Notes for table 11:

1. Probabilities of release sizes were estimated from PNW description of release, assuming that 25% of the time the rail car overturned (see Stewart, 1990). Damage estimates were generated using the computer model IRR (1987) and Van Aerde et al. (1988).

2. Probabilities of release sizes were estimated from AAR description of release, and asssuming that 25% of the time the railcar overturned (Stewart, 1990). Damage estimates for the risk analysis were generated with a modified version of the computer model IRR (1987).

3. Release size distribution was estimated from Transport Canada LPG truck release data (Stewart, 1990). Damage estimates were estimated as in note 1 above.

4. Release size distribution was estimated from Transport Canada Gasoline truck release data (Stewart, 1990). Damage estimates were estimated as in note 2 above.

associated with the overall risk estimates for different component inputs. Figure 2 indicates that if the full range of inputs was considered in risk estimation, final risk estimates could vary by as much as ten orders of magnitude. This lack of reliability in the results of the risk analysis process for the transport of hazardous materials raises serious questions of how best to communicate uncertainty so that the process itself does not lose credibility. It is clear from this analysis, that a single risk estimate cannot be obtained with any degree of reliability, and that any estimate must be accompanied by the associated envelope of uncertainty.

The weakest-link caveat is also invoked by the results of Figure 2. This refers to the rate of return in risk reliability obtained through improvements in submodel precision, particularly the dispersal relationships associated with selected hazardous materials. To improve reliability, submodel improvements must be undertaken with a full understanding of their effect in reducing uncertainties in overall risk estimates. One possible approach to the difficulties posed by Figure 2 is to develop criteria for systematically reducing uncertainty in the various constituent components of risk. These criteria could then be used to allocate available resources so the highest level of improvement in reliability can be realized. For example, it may be preferred to improve the databases on accidents and accompanying releases prior to undertaking refinements in damage propagation submodels or the computer presentation of the hazard area analysis (e.g., three-dimensional imagery).

Figure 2 presents an interesting quandary for the subsequent communication of risk to the public and to decision makers. Given the inherent uncertainties in its estimation, how can risk be effectively communicated to decision makers so that uncertainty comprises an integral part of the process? The results of this paper suggest there is a very real limit to the usefulness of a process that does not consider

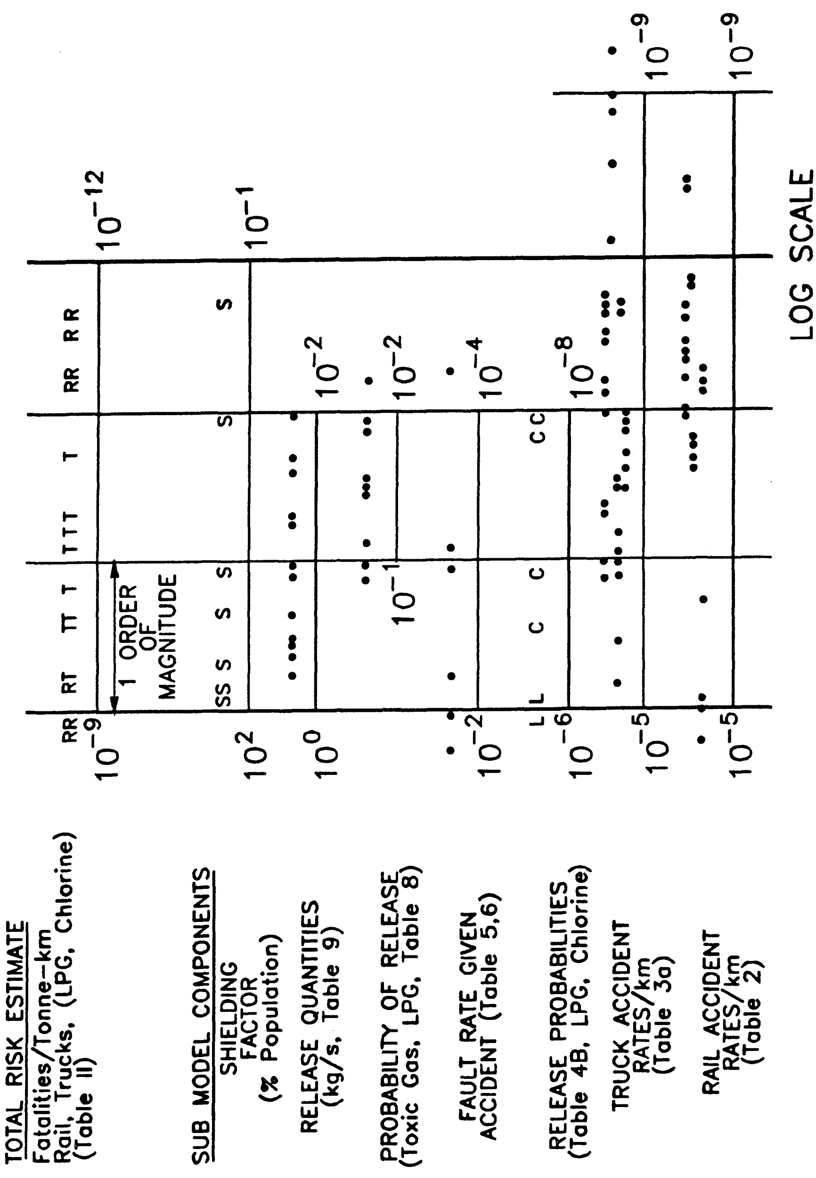


Figure 2 Variations in risk component estimates

the practical implications of a very high level of uncertainty in estimation. Risk measures that ignore these associated uncertainties are likely to result in unnecessary controversy, and it is doubtful that these measures will provide an effective basis for the development of appropriate safety protocols.

CONCLUSIONS

The development of risk estimates for the movement of dangerous goods has been set in a framework of submodels that includes: accidents, failure of containment, characteristics of spills, dispersion of hazardous substances, and finally, impact on people, property and the environment. It is proposed that all of these model components are equally critical in the development of the overall risk estimate for use in policy making.

A review of the literature on risk estimation has shown that ranges of two to three orders of magnitude are typical for most risk components. Uncertainty in risk component estimation results from a number of sources, such as model structure, underlying assumptions of application, databases used to specify and validate the models, omissions in model inputs, and a general tendency towards "conservatism" in the treatment of uncertainty. In addition there are major uncertainties caused by the application of the process itself. These uncertainties are due to such factors as the nature of the material being considered, the transport environment, population density at the accident site, and response from emergency forces.

This paper has developed a framework for understanding the nature of uncertainty in risk model estimates. The intent of this work is to provide a basis for considering uncertainty as an integral part of the risk analysis process. This paper proposes that further work be directed to providing answers to the following questions:

1. What are the existing ranges of estimates for each submodel?

2. What is an acceptable range of uncertainty for each submodel, and how much effort needs to be expended to achieve this level of consistency?

3. What are the limitations placed on the estimation of risks for hazardous material transport by the practical considerations of communicating the risks to decision makers and public?

4. What priorities should be established for improving risk estimation methods, and where should existing research effort be directed?

REFERENCES

Association of American Railroads. 1986. *Hazardous Materials Statistics.* Hazardous Materials Systems, 3140 South Federal Ave., Chicago, Illinois, 60616.

Buyco, C. and Saccomanno, F. 1988. "Analysis of Truck Accident Rates Using Loglinear Models." *Canadian Journal of Civil Engineering*, Vol.15, No.3, June.

Coleman, J. and Stewart, G. 1976. "Investigation of Accident Data for Railroad-Highway Grade Crossings." Proceedings, National Conference of Railroad-Highway Grade Crossings Safety.

Doswell, S., de Malherbe, R., de Malherbe, M. and Uhm, I. 1986. "The Performance of North American Railways with Hazardous Materials: Historical Trends and Predictive Risk Estimation." *Tribune de Transports*, Vol.3-1, June.

Glickman, T. and D. Rosenfield. 1984. "Risk of Catastrophic Derailments involving the Release of Hazardous Materials." *Management Science*, Vol. 30, No. 4., April.

Grange, G.M. 1980. "Report of the Missisuaga Railway Accident Inquiry." *Ministry of Supply and Services*, Ottawa, Ontario, Canada.

Harwood, E. and E. Russell. 1989a. *Present Practices of Highway Transportation of Hazardous Materials*. Report No. FHWA-RD-89-013, Prepared by the Midwest Research Institute, for the Office of Safety and Traffic Operations R&D, Federal Highway Administration, McLean, Virginia.

Harwood, D., J. Viner, and E. Russell. 1989b. *Characteristics of Accidents and Incidents in Highway Transportation of Hazardous Materials*. Presented at the 68th Annual Meeting of the Transportation Research Board, Washington, D.C., January 22-26.

Hubert, P., P. Pages, and J. P. Degrange. 1988. *Regional estimation of the risk involved in the transportation of dangerous materials: Comparison of road transport routes at Lyons*. CEPN Report No. 1

Hubert, P. 1985. *Risks of major accidents in the transportation of dangerous materials.* Report D.114, CEPN, France, Presented at a Conference in France, November.

Institute for Risk Research. 1987. "Risk Management in the Handling and Transportation of Dangerous Goods." Final Report prepared for the Transportation of Dangerous Goods Directorate, Transport Canada, February.

Pacific Northwest Laboratory. 1980. *An Assessment of the Risk of Transporting Propane by Truck and Train*. Prepared for the U.S. Department of Energy, C.A. Geffen, Project Coordinator, Richland, WA.

Purdy, G., H. Campbell, G. Grint, and L. Smith. 1988. "An Analysis of the Risks Arising from the Transport of Liquefied Gases in Great Britain." *Journal of Hazardous Materials* 20:335-355, Elsevier Science Publishers, Amsterdam.

Purdy, G., Technica Ltd, and Environmental Resources Ltd., with Watson Hawksley Asia. 1989. *Tsing Yi Hazard Potential, Principal Findings.* A Study for Public Works Department, Hong Kong Government.

Purdy, G. 1990. "Discussion on the paper: Fatality Risk Curves for Transporting Chlorine and Liquified Petroleum Gas by Truck and Rail." *Transportation Research Record*, No. 1264, pp. 42-44.

Raj, P. and T. Glickman. 1985. "Generating Hazardous Material Risk Profiles on Railroad Routes." Proceedings, Conference on Recent Advances in Hazardous Materials Transportation Research: An International Exchange, Transportation Research Board, November, 10-13.

Saccomanno, F. F., J. H. Shortreed and R. Mehta 1990. "Fatality Risk Curves for Transporting Chlorine and Liquefied Petroleum Gas by Truck and Rail." *Transportation Research Record*, No. 1264, pp. 29-41.

Saccomanno, F. F., J. H. Shortreed , M. Thomson. 1990. "Fault Tree Analysis of Pressure Liquefied Gases from In-Transit Rail Bulk Tankers." *Forensic Engineering*, Vol. 2, No. 3, pp. 357-369.

Sparks, G., J. Bielka, A. Smith, D. Marzolf, and R. Neudorf. 1988. *The Safety Experience of Large Trucks in Saskatchewan.* Report prepared for Saskatchewan Highways and Transportation and Transport Canada.

Stewart, A.M. 1990. *The Development of a Risk Based Procedure for Evaluating Transport of Dangerous Goods Policies.* MSc Thesis, Queen's University, Kingston, Ontario.

The Netherlands Organisation for Applied Scientific Research (TNO). 1988. *Enclosures to be used in conjunction with the Guide to hazardous industrial activities.* Research for the Fire Service Directorate of the Ministry of Home Affairs and the Transport and Public Works Department of the Province of South Holland, The Hague, September.

Toronto Area Rail Transportation of Dangerous Goods Task Force. 1988. *Final Report.* Prepared for the Honourable Benoit Bouchard, Minister of Transport, Available from the Minister of Supply and Services Canada, Catalogue no. T44-3/14 E.

Van Aerde, M., J. Shortreed, A. M. Stewart, and M. Matthews. 1989. "Assessing the Risks Associated with the Transport of Dangerous Goods By Truck and Rail Using the RISKMOD Model." *Canadian Journal of Civil Engineering*, Vol.X, June.

Wade, P., and associates. 1986. *A Strategic Overview: Hazardous Goods Transportation by Rail in Toronto*. Report submitted to the City of Toronto, Planning and Development Department, November.

12

PERCEPTIONS OF RISK: PARADOX AND CHALLENGE

Paul Slovic

Perceived risk can be characterized as a battleground marked by strong and conflicting views about the nature and seriousness of the risks of modern life. The paradox for those who study risk perception is that, as people in many industrialized nations have become healthier and safer on average, they have become more—rather than less—concerned about risk, and they feel increasingly vulnerable to the risks of modern life (see, for example, figure 1). The stakes are high! These perceptions and the opposition to technology that accompanies them have puzzled and frustrated industrialists and regulators in many nations and have led numerous observers to argue that the apparent pursuit of a "zero-risk society" threatens political and economic stability in those nations (see table 1). Aaron Wildavsky, a political scientist, commented as follows on this state of affairs:

> How extraordinary! The richest, longest lived, best protected, most resourceful civilization, with the highest degree of insight into its own technology, is on its way to becoming the most frightened.
>
> Is it our environment or ourselves that have changed? Would people like us have had this sort of concern in the past? . . . Today, there are risks from numerous small dams far exceeding those from nuclear reactors. Why is the one feared and not the others? Is it just that we are used to the old or are some of us looking differently at essentially the same sorts of experience?

Studies of risk perception attempt to understand why people's concerns are increasing and why it is that perceptions are so often at variance with what the experts say people should be concerned about.

Why are we getting more concerned about risk as we become safer and healthier on average? Although research has not yet provided a complete answer to this question, I have several hypotheses about factors that probably are contributing to perceptions of increased risk.

One factor is that we have greater ability to detect minute levels of toxic substances. We can detect parts per billion or trillion or even smaller amounts of chemicals in water and air and in our own bodies. At the same time, we have great difficulty understanding the health implications of this new knowledge.

Second, we have an increasing reliance on powerful new technologies that can

Figure 1. Risk today versus 20 years ago. Results from a 1988 survey in Sweden. Source: Slovic et al. (1989).

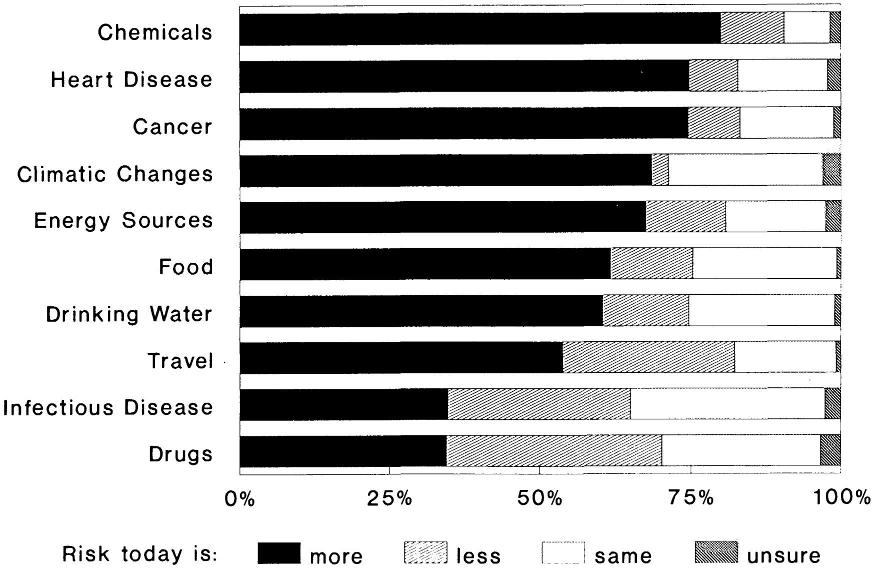


Table 1. Excerpts from a 1987 speech by Elizabeth Whelan, Executive Director, American Council on Science and Health.

- Our public health priorities in the U.S. are inverted and confused.
- As a nation in pursuit of good health we are squishing ants and letting the elephants run wild.
- This may be one of the most critical domestic issues facing the U.S. today.
- It is wasteful and unprincipled to chase after chemical residues in our food when cigarettes, AIDS, alcohol, and drug abuse are costing hundreds of thousands of lives, billions upon billions of dollars, and untold human suffering.
- I believe that the growing fear of technology and the associated regulatory effort to purge our land of hypothetical risks at any cost is economic suicide.

have serious consequences if something goes wrong. When we lack familiarity with a technology we are naturally suspicious of it and cautious in accepting its risks.

Third, we have experienced a number of spectacular and catastrophic mishaps, such as Three Mile Island (TMI), Chernobyl, Bhopal, and the *Challenger* accident. These get extensive media coverage, which highlights the failure of supposedly "fail-safe" systems.

Fourth, we have an immense amount of litigation over risk incidents, which brings problems to public attention and pits expert against expert—leading to loss of credibility on all sides.

Fifth, the benefits from technology are often taken for granted. When we fail to perceive significant benefit from an activity, we are intolerant of any level of risk.

Sixth, we are now being told that we have the ability to control many elements of risk. For example, we can wear seatbelts, change our diets, get more exercise, and so on. Perhaps the increased awareness that we have control over many risks makes us more frustrated and angered at those risks that we are not able to control, when exposures are imposed upon us involuntarily (e.g., air pollution, pesticides, or food additives).

Seventh, psychological studies indicate that when people are wealthier and have more to lose, they become more cautious in their decision making.

Finally, there may be real changes in the nature of today's risks. For example, there may be greater potential for catastrophe than there was in the past, due to the complexity, potency, and interconnectedness of technological systems and the widespread exposure of millions of people to new technologies and substances. A case in point is the sweetener aspartame, which only a few years after its introduction is used by hundreds of millions of people daily. If some potential hazard has been missed in the testing of this chemical (as happened with the drug thalidomide), the potential for harm is enormous.

PSYCHOMETRIC STUDIES

During the past decade, a small number of researchers has been studying risk perception by examining the judgments people make when they are asked to characterize and evaluate hazardous activities and technologies (Slovic, 1987). One broad strategy for studying perceived risk is to develop a taxonomy for hazards that can be used to understand and predict responses to their risks. The most common approach to this goal has employed the *psychometric paradigm,* which produces quantitative representation or "cognitive maps" of risk attitudes and perceptions. Within the psychometric paradigm, people make quantitative judgments about the current and desired riskiness of various hazards. These judgments are then related to judgments of other properties, such as the hazard's status on characteristics that have been hypothesized to account for risk perceptions (e.g., voluntariness, dread, catastrophic potential, controllability). These characteristics of risk tend to be highly correlated with each other, across the domain of hazards. For example, hazards judged to be catastrophic also tend to be seen as uncontrollable and involuntary.

Investigation of these relationships by means of factor analysis has shown that the broad domain of risk can be reduced to a small set of higher-order characteristics or "factors."

The factor spaces shown in figures 2 and 3 have been replicated often. Factor 1, labeled "Dread Risk," is defined at its high (right-hand) end by perceived lack of control, catastrophic potential, and fatal consequences. Factor 2, labeled "Unknown Risk," is defined at its high end by hazards perceived as unknown, unobservable, new, and delayed in their manifestation of harm.

Research has shown that lay people's perceptions of risk are closely related to these factor spaces. In particular, the further to the right a hazard appears in the space, the higher its perceived risk, the more people want to see its current risks reduced, and the more people want to see strict regulation employed to achieve the desired reduction in risk. In contrast, experts' perceptions of risk are not closely related to any of the various risk characteristics or factors derived from these characteristics. Instead, experts appear to see riskiness as synonymous with expected annual mortality. As a result, conflicts over "risk" may result from experts and lay people having different definitions of the concept.

In addition to examining factor spaces, it is instructive to compare perceptions of risk and benefit for various radiation technologies with perceptions of various chemical technologies. Concerns about chemical risks have risen dramatically in the past decade, spurred by well-publicized crises at Love Canal, Times Beach, and many other waste sites; by major accidents at Seveso, Bhopal, and Valdez; and by numerous other problems such as the contamination of ground water and flour with the pesticide ethylene dibromide (EDB) and the recent flap regarding the use of Alar, a growth regulator, in apples. The image of chemical technologies is so negative that when you ask college students or members of the general public to tell you what first comes to mind when they hear the word "chemicals," by far the most frequent response is "dangerous" or some synonym (e.g., toxic, hazardous, poison, deadly); beneficial uses of chemicals are rarely mentioned (see table 2). Chemicals in general and agricultural and industrial chemicals in particular are seen as very high in risk and very low in benefit, as are nuclear power and nuclear-waste technologies. However, medical uses of radiation (such as x-rays) are perceived in a very favorable way, differently from other radiation technologies; so are prescription drugs, which are a very potent and toxic category of chemicals to which we are often exposed at high doses. Figure 4, taken from a study in Sweden, illustrates the parallels between nuclear power and nonmedical chemicals (pesticides, alcohol) seen as high in risk and low in benefit and x-rays and prescription drugs such as antibiotics and medicines for arthritis (high benefit/low to moderate risk). A national survey in Canada has shown much the same results.

SOCIAL AMPLIFICATION OF RISK

Risk analysis typically models the impacts of an unfortunate event (such as an accident, a discovery of pollution, sabotage, product tampering) in terms of direct

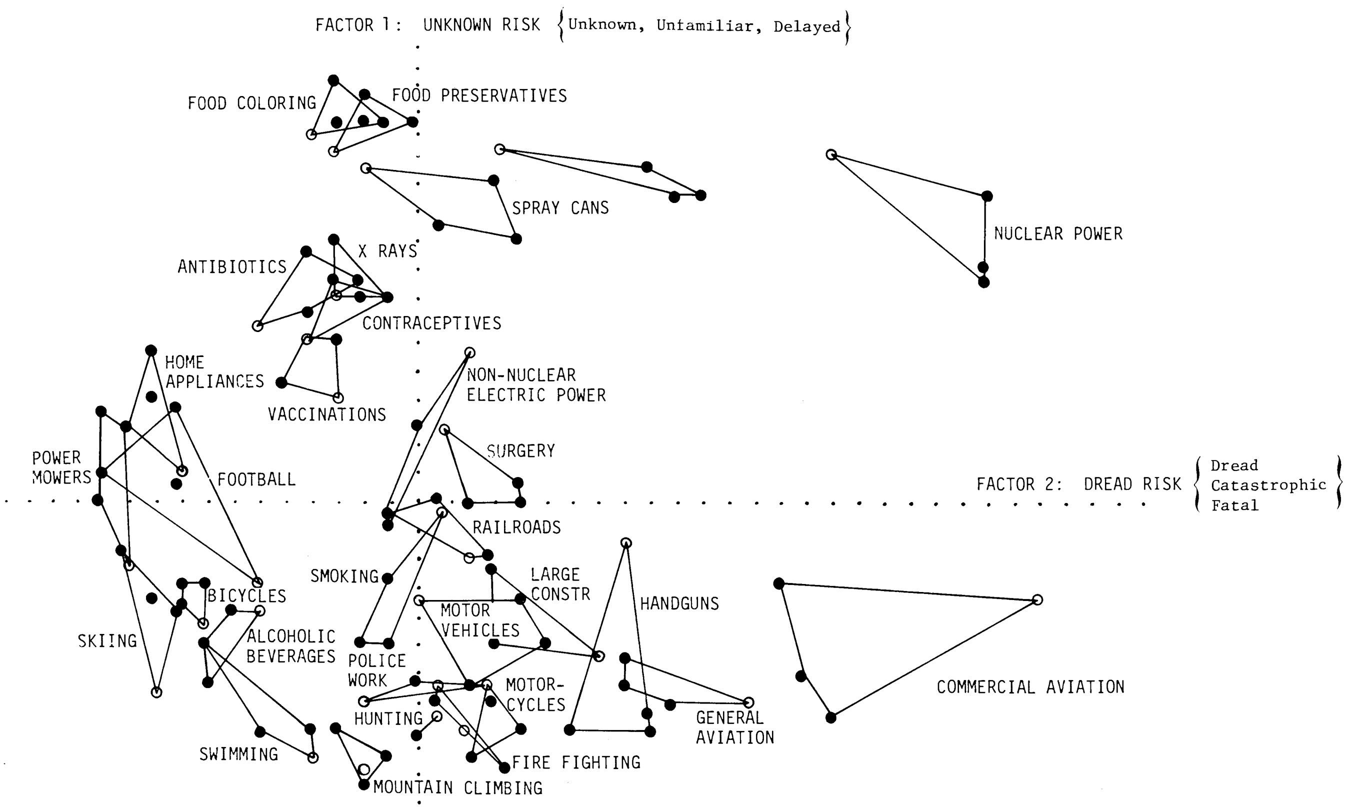
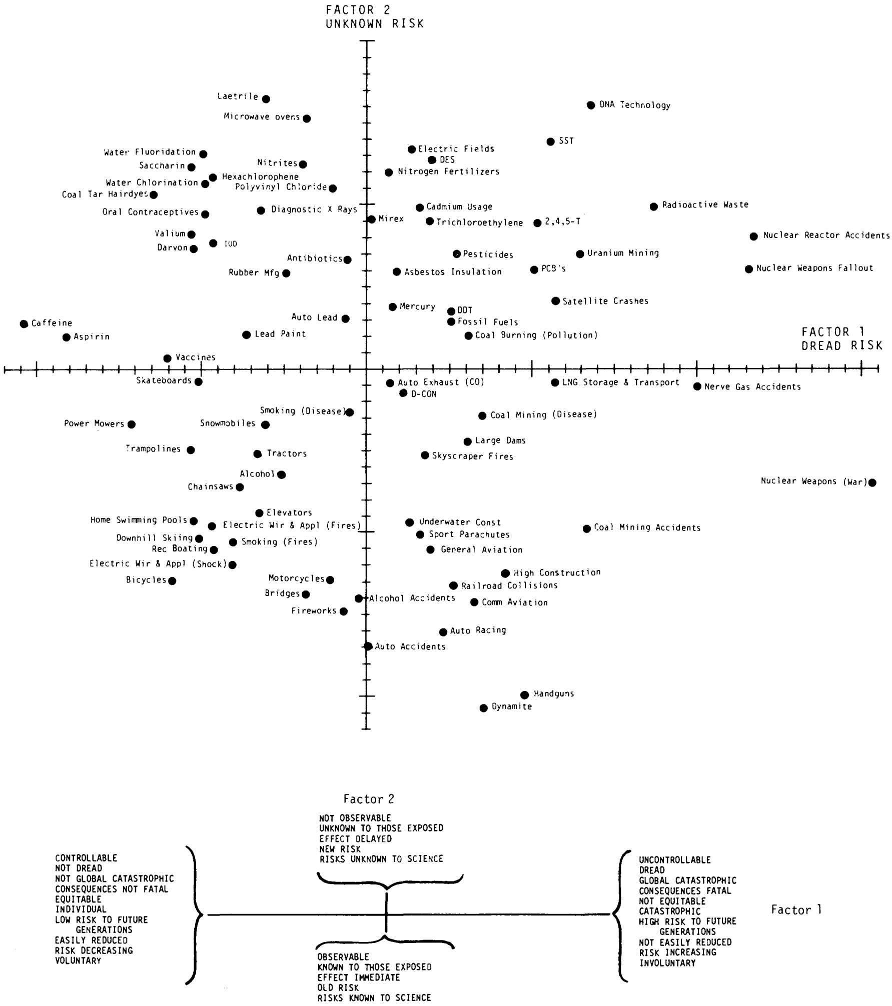


Figure 2. Location of 30 hazards within the two-factor space obtained from League of Women Voters, student, Active Club, and expert groups. Connected lines join or enclose the loci of four group points for each hazard. Open circles represent data from the expert group. Unattached points represent groups that fall within the triangle created by the other three groups. Source: Slovic, Fischhoff, and Lichtenstein (1985).

Figure 3. Location of 81 hazards on factors 1 and 2 derived from the relationships among 18 risk characteristics. Each factor is made up of a combination of characteristics, as indicated by the lower diagram. Source: Slovic, Fischhoff, and Lichstenstein (1985).



harm to victims—deaths, injuries, or damages. The impacts of such events, however, sometimes extend far beyond these direct harms, and may include significant indirect costs (both monetary and nonmonetary) to the responsible government agency or private company that far exceed direct costs. In some cases, all companies in an industry are affected, regardless of which company was responsible for the mishap. In extreme cases, the indirect costs of a mishap may extend past industry boundaries, affecting companies, industries, and agencies whose business is minimally related to the initial event. Thus, an unfortunate event can be thought of as analogous to a stone dropped in a pond. The ripples spread outward, encompassing first the directly affected victims, then the responsible company or agency, and, in extreme cases, reaching other companies, agencies, and industries. This proliferation of impacts is an important element of the phenomenon that has been termed "the social amplification of risk" (Kasperson, Renn, and Slovic et al., 1988).

Some unfortunate events make only small ripples; others make larger ones. One important challenge for research is to discover characteristics associated with an event and how it is managed that can help predict the breadth and seriousness of those impacts (see figure 5). Early theories equated the magnitude of impact to the number of people killed or injured, or to the amount of property damaged. However, the accident at the Three Mile Island nuclear reactor in 1979 provided a dramatic demonstration that factors besides injury, death, and property damage impose serious costs. Despite the fact that not a single person died at TMI, and few if any latent cancer fatalities are expected, no other accident in our history has produced such costly societal impacts. The accident at TMI devastated the utility that owned and operated the plant. It also imposed enormous costs (estimated at $500 billion by one source) on the nuclear industry and on society, through stricter regulation (resulting in increased construction and operation costs), reduced operation of reactors worldwide, greater public opposition to nuclear power, and reliance on more expensive energy sources. It may even had led to a more hostile view of other complex technologies, such as chemical manufacturing and genetic engineering.

Although the TMI accident is extreme, it is by no means unique. Dramatic recent examples of events whose social and economic impacts were far out of proportion to their demonstrable risks were the controversy over Alar in apples and the Chilean grape scare. Other recent events that resulted in enormous higher-order impacts include the chemical manufacturing accident at Bhopal, India; the pollution of Love Canal, New York, and Times Beach, Missouri; the disastrous launch of the space shuttle Challenger; and the meltdown of the nuclear reactor at Chernobyl. Following these extreme events are a myriad of mishaps varying in the breadth and size of their impacts.

It appears likely that multiple mechanisms contribute to the phenomenon of social amplification. First, a large amount of media coverage of an event could contribute to heightened perceptions of risk, particularly if the information reported was exaggerated or distorted.

Second, a particular risk or risk event may enter into the agenda of social groups, or what sociologist Allan Mazur terms the *partisans*, within the community or nation. This may occur either because a particular group has goals that include

Table 2. College Students' Word Associations to the Stimulus Term "Chemicals"

Category	Frequency	Responses
Dangerous	59	dangerous, toxic, hazardous, deadly, destruction, accidents, poisonoius, explosive, kill, harmful, Bhopal, cancer, bad, noxious
Chemical names and elements	45	H_2SO_4, ozone, carbon, dioxin, gas, DDT, cyanide, methane, hydrogen, monoxide, oxygen, uranium, acid
Pollution	29	Love Canal, greenhouse effect, smelly, Teledyne Wah Chang, air pollution
Laboratory	30	experiments, science
Chemical types	21	herbicides, pesticides, preservatives, vitamins, fertilizer, drugs, medicines
Chemistry	16	
Useful	14	beneficial, jobs, benefits, valuable, products, helpful
Wastes	10	
Food	9	
"Paraphanelia"	11	beaker, bottles, flasks, litmus, test tubes, hood, stockroom
Burn	12	burner, Bunsen-Burner, burning
DOW	6	
War	11	warfare
Technology	7	industry

Figure 4. Perceived risk and perceived benefit based on a survey in Sweden.
Source: Slovic et al. (1989).

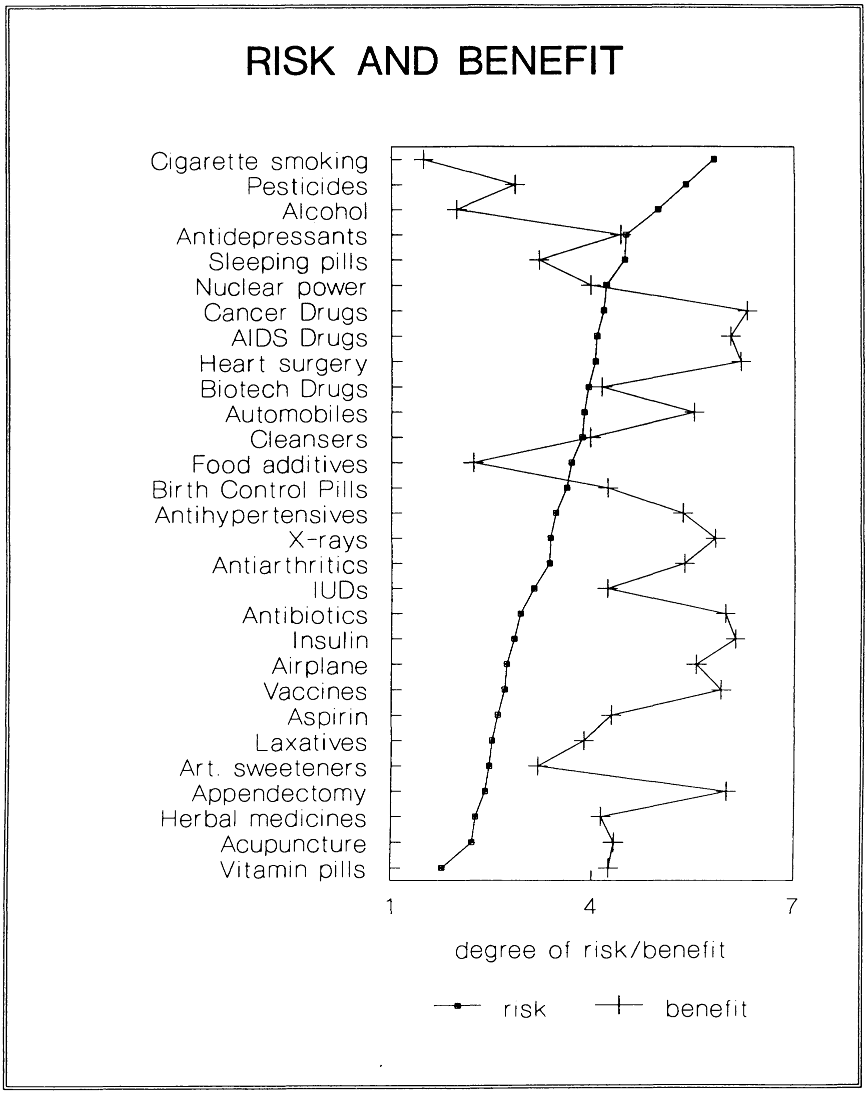
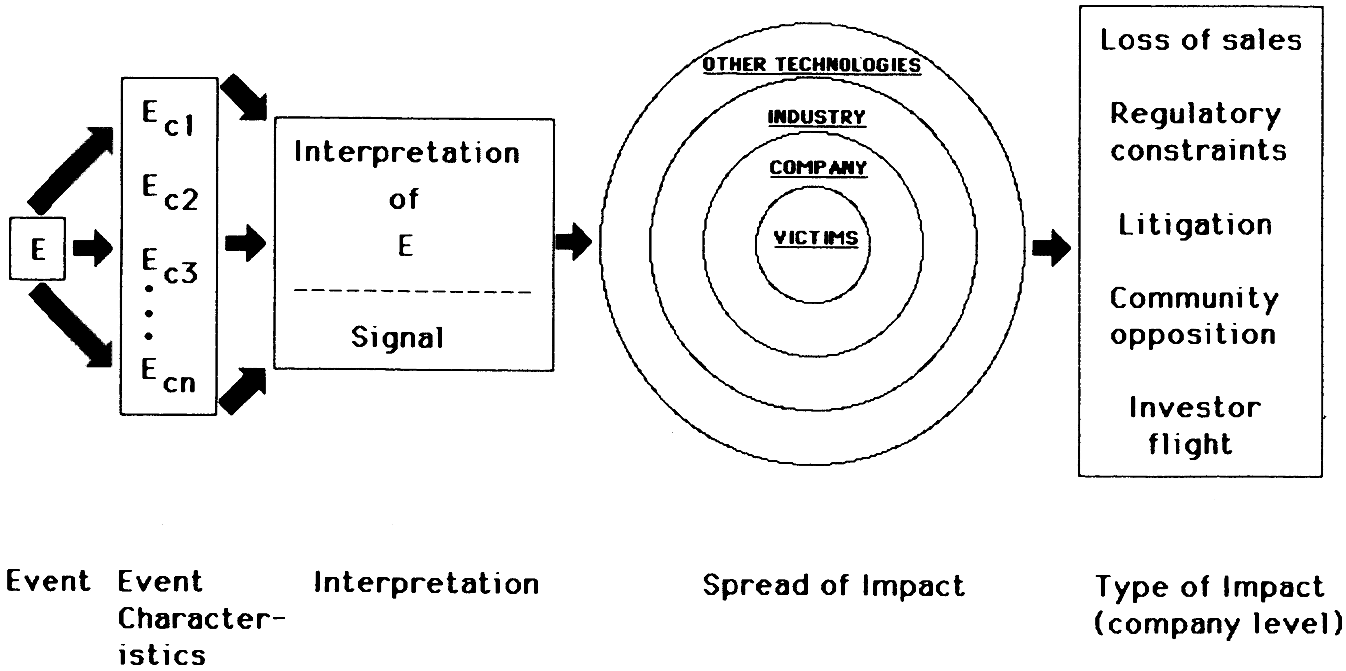


Figure 5. A preliminary model of impact for unfortunate events. Development of the model will require knowledge of how the characteristics (E_c) associated with a hazard event interact to determine the interpretation or message drawn from that event. The nature of the interpretation is presumed to determine the type and magnitude of ripple effects. Source: Kasperson et al. (1988).



this risk issue or simply because political advantage is to be gained by exploiting this particular risk (Alar is an example of this point). To the extent that risk becomes a central issue in a political campaign or conflict among social groups, it will be vigorously brought to public attention, often coupled with an ideological interpretation of the risk-management process. Polarization of views and escalation of rhetoric by the partisans are frequent results. These social alignments tend to become anchors for subsequent interpretation of risk management and may become quite firm in the face of conflicting information.

A third mechanism of amplification arises out of the interpretation of unfortunate events as cues or signals regarding the magnitude of the risk and adequacy of the risk-management process. The informativeness or *signal potential* of a mishap, and thus its potential social impact, appears to be systematically related to the characteristics of risk and the factor spaces shown in figures 2 and 3. An accident that takes many lives may produce relatively little social disturbance (beyond that caused the victims' families and friends) if it occurs as part of a familiar and well-understood system (e.g., a train wreck). However, a small accident in an unfamiliar system (or one perceived as poorly understood), such as a nuclear reactor or a recombinant DNA laboratory, may have immense social consequences if it is perceived as a harbinger of future and possibly catastrophic mishaps.

The concept of accidents as signals helps explain why people reacted so strongly to the news that certain foods contained small amounts of the carcinogenic pesticide ethylene dibromide (EDB). Although EPA assured the public that the risks were minute and the pesticide was being removed from use, the hidden message or signal, as revealed in several newspaper editorials, was disturbing. One editor wrote: "The cumulative effect—the 'body burden count' as scientists call it—is especially worrisome considering the number of other pesticides and carcinogens humans are exposed to" (*The Sunday Star-Bulletin and Advertiser*, Honolulu, February 5, 1984). On the same topic, another editor wrote: "Let's hope there are no cousins of EDB waiting to ambush us in the months ahead" (*San Francisco Examiner*, February 10, 1984).

As a result of this broad (and legitimate) perspective, communications from risk managers pertaining to the risk and control of a *single* hazard, no matter how carefully presented, may fail to alleviate people's fears, frustrations, and anger. However, if people trust the ability of the risk manager to handle risk problems, these broader concerns will probably not surface.

Adverse events involving hazards in the upper-right quadrant of figures 2 and 3 appear particularly likely to produce large ripples, because of the (perceived) unknown, dread, and catastrophic qualities of these hazards. We have also found that hazards in the upper-left quadrant (including medicines and food chemicals) also have the potential to produce large ripples when something goes wrong. As a result, risk-impact analyses and decisions involving these hazards need to take possible higher-order impacts into consideration. Further research may be able to give precise guidance to decision makers about the probability and severity of these impacts.

PSYCHOMETRIC STUDIES OF TRANSPORTATION HAZARDS

The earliest psychometric studies were distinguished by their comparisons of large hazard sets containing items as diverse as bicycles and nuclear power plants. Factor analysis of relationships among these items produced what might be called a "global space" as shown in figures 2 and 3. A question, of both theoretical and practical significance, is whether the global structure would also pertain to a "local" set of hazards, all falling within the same general category. For example, one point in figure 3 represents the technology "railroad collisions." But all railroad accidents may not be the same. Would a taxonomy consisting solely of railroad accidents have the same factor structure as figure 3?[1]

To answer this question, Kraus and Slovic (1988) put the railroad collisions point "under a microscope" to examine its structure. We constructed 49 railroad accident scenarios based on combinations of the following components:

- Type of train: traditional, high speed, rapid transit
- Type of cargo: passengers, benign cargo (e.g., grain), chemicals
- Type of accident: two-train collision, train-car collision, derailment
- Location of accident: tunnel, open ground, bridge, grade crossing, mountain pass
- Cause of accident: human error, sabotage, earthquake, mechanical failure

Each railroad scenario was rated by 50 subjects on perceived riskiness as well as on 10 additional characteristics prominent in previous taxonomies of perceived risk. Several other hazards, such as nuclear reactors, fire fighting, bicycles, and DNA research were also rated to help calibrate the railroad data.

Psychometric analysis of these data showed considerable similarity between the railroad space and previous representations based on diverse hazards. The railroad space was well represented by two factors in which knowledge and catastrophic potential played defining roles. The results also demonstrated that not all rail hazards are well represented by the point labeled "railroad collisions" in figure 3. A train carrying explosive chemicals near a city was perceived to be more like a nuclear reactor than like other rail hazards. A train carrying non-toxic freight evoked little concern. The heterogeneity of railroad hazards has important practical

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1. The answer is not intuitively obvious. Local and global representations have the same dimensions for some objects (e.g., rectangles are always defined by height and width no matter how similar or dissimilar they are), whereas the dimensions needed to represent diverse emotions such as love, pride, worry, or anger differ from the local dimensions needed to characterize the various aspects of a single emotion such as love—puppy love, maternal love, and so on (Gerrig, Maloney, & Tversky, 1985).

implications that are linked to our earlier discussion of signal value, social amplification and impact (see figure 5). It may be important for policy makers and system designers to know that there is a substantial difference between the degree of concern people show for an ordinary freight train derailment and the enhanced concern (and social disruption) likely to be associated with the derailment of a train carrying toxic chemicals. Thus, representing railroad accidents as a single, homogeneous category may be quite misleading as a predictor of societal response to specific railroad hazards and accidents.

This latter point was made again in a follow-up study by Slovic, MacGregor, and Kraus (1987) which examined perceptions of risk and signal value for 40 structural defects in automobiles of the kind that compel manufacturers to initiate a recall campaign. The defects were diverse, ranging from faulty defrosters to gasoline fumes that enter the passenger compartment to problems that reduce the effectiveness of steering or braking systems. Each defect was rated on a set of risk-characteristic scales that included overall vehicle riskiness, manufacturer's ability to anticipate the defect, severity of possible consequences, observability, and likelihood that the rater would comply with the recall notice (bring the car in for repair) if the defect occurred in the rater's automobile. A factor analysis indicated that these judgments could be summarized in terms of two composite factors, one representing the possibility of severe, uncontrollable damage and the other representing the foreseeability of the defect by the manufacturer. Within this two-dimensional representation, the defects were perceived quite differently, as shown in figure 6. Perceived risk, rated personal compliance with a recall notice, and actual compliance rates for the defects were all highly predictable from location within the factor space ($R = .89$, .81, and .55, respectively). One defect stood out much as nuclear power does in figure 2. It was a fuel-tank rupture upon impact (labeled FUELRPTR), creating the possibility of fire and burn injuries. This, of course, is similar to the notorious design problem that plagued the Ford Pinto and that Ford allegedly declined to correct because a cost-benefit analysis indicated that the correction costs greatly exceeded the expected benefits from increased safety (*Grimshaw v. Ford Motor Company*, 1978). Had Ford done a psychometric study, the analysis might have highlighted this particular defect as one whose seriousness and higher-order costs (lawsuits, damaged company reputation) were likely to be greatly underestimated by their cost-benefit analysis.

MacGregor and Slovic (1989) subsequently applied a similar analysis to 30 automobile subsystems, including braking, steering, suspension, engine, signaling, electrical, and fuel systems. Comparisons between perceptions of risk and data on accident causes showed that drivers recognized the importance of brakes but underestimated the risks posed by faulty communication and signaling systems such as headlights, brake lights, marker lights, turn signals, and horn.

RISK COMMUNICATION

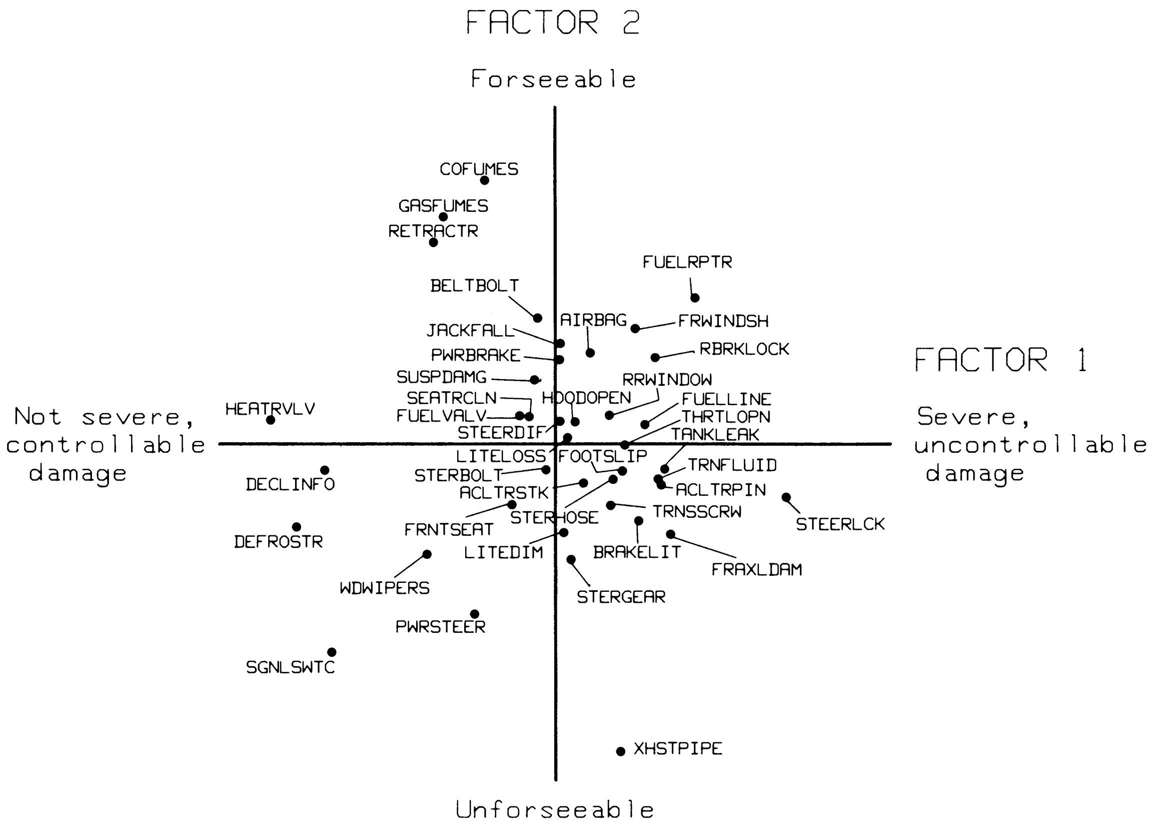
Analysis of risk perception leads very naturally to the topic of risk communication. There is a great need to help people put risk into perspective. Yet communication must not be merely one-way (expert to public). It needs to be a two-way process, based on trust and mutual respect. Each side has something to learn from the other. The experts' models and assessment methods are very sophisticated, but they tend to focus on the more easily quantified elements of risk. Lay people have a much broader, more qualitative view of risk. You can't say that they are wrong to be concerned about risk to future generations, catastrophic potential, issues of voluntary vs. involuntary exposure, inequitable distributions of risk and benefit, and so on. These are value issues which need to be respected and integrated appropriately into risk-management decisions.

The crux of the communication problem is providing information that puts risk into perspective in a way that facilitates decision making. In this regard, one important lesson emerged from the controversy over EDB. The Environmental Protection Agency, which was responsible for regulating EDB, disseminated information about the aggregate risk of this pesticide to the exposed population. Although the media accurately transmitted EPA's "macro" analysis, newspaper editorials and public reaction clearly indicated an inability to translate this into a "micro" perspective on the risk to an exposed individual. What the newspaper reader or TV viewer wanted to know, and had trouble learning, was the answer to the question: "Should I eat the bread?"

One of the few "principles" in this field that seems to be useful is the assertion that comparisons are more meaningful than absolute numbers or probabilities, especially when these absolute values are quite small. One proponent of risk comparisons argued that to decide whether or not we are responding adequately to a particular type of risk we need to compare it to "some of the other risks of life." Another analyst observed, "There is no point in getting into a panic about the risks of life until you have compared the risks which worry you with those that don't, but perhaps should."

Typically, such exhortations are followed by elaborate tables and even "catalogs of risks" in which diverse indices of death or disability are displayed for a broad spectrum of life's hazards. One such table showing risks per hour of exposure indicates, for example, that an hour riding a motorcycle is as risky as an hour of being 75 years old. Although such risk comparisons may provide some aid to intuition, they do not educate as effectively as their proponents have assumed. One reason for this is that the research on risk perception described earlier shows that perception and acceptance of risk are determined not only by risk measures such as accident probabilities, annual mortality rates, and losses of life expectancy, but also by numerous other characteristics of hazards such as uncertainty, controllability, catastrophic potential, equity, and threat to future generations. Within the perceptual space defined by such characteristics, each hazard is unique. A statement such as "the annual risk from living near a nuclear power plant is equivalent to the risk of riding an extra 3 miles in an automobile" fails to consider that these two activities

Figure 6. Location of 40 automobile defects within a two-factor space derived from interrelationships among five characteristics. Source: Slovic, MacGregor, and Kraus (1987).



differ on many qualities that are important to people. As a result, such statements are likely to produce anger rather than enlightenment.

Perception of benefit is another quality that is neglected in many comparisons. For example, biochemist Bruce Ames' statement that "the cancer risk of eating apples containing Alar is equivalent to the risk of drinking tap water (which contains chloroform) and is 30 times lower than the risk of eating peanut butter (which contains aflatoxins)" was ineffective in producing acceptance of Alar. The explanation is that Alar was perceived to have little benefit to the consumer, in sharp contrast to tap water or peanut butter (both of which are also much more familiar hazards than Alar).

In sum, comparisons across diverse hazards may be useful tools for educating the public. Yet the facts do not speak for themselves. Comparative analyses must be performed with great care to be worthwhile.

CONCLUDING REMARKS

Although many observers have labeled public perceptions of risk *irrational*, the research that I have described above paints a much different picture. First, whereas experts define risk in a narrow, quantitative way, the public has a wider view, qualitative and complex, incorporating legitimate value-laden considerations such as uncertainty, dread, catastrophic potential, and controllability into the risk-benefit equation.

Second, perceptions of risk appear to be a product of the kind of society in which we live. Our participatory form of democracy, our intrusive media, our powerful special interest groups, and our penchant for litigation combine to overpower the young science of risk assessment. No one is happy about this state of affairs; industrialists, scientists, politicians, and the public are united in their anger and frustration about the ways risks are currently managed.

Perception of risk is a reality in itself, with great impact on our way of life. This impact cannot be lessened without drastic and politically unacceptable changes in the structure of our societies. Thus we must learn to treat perceptions as legitimate. We must attempt to understand them and to incorporate public concerns and wisdom into the decision-making process, along with the wisdom gleaned from scientific risk assessments.

REFERENCES

Gerrig, R. J., Maloney, L. T., and Tversky, A. 1985. *Dimensional invariance in psychological spaces: Personality traits and emotional states.* Unpublished manuscript, Stanford University, Department of Psychology.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., Kasperson, J. X., and Ratick, S. 1988. "The social amplification of risk: A conceptual framework." *Risk Analysis*, 8:177-187.

Kraus, N. N., and Slovic, P. 1988. "Taxonomic analysis of perceived risk: Modeling individual and group perceptions within homogeneous hazard domains." *Risk Analysis*, 8:435-455.

MacGregor, D., and Slovic, P. 1989. "Perception of risk in automotive systems." *Human Factors*, 31(4): 377-389.

Slovic, P. 1987. "Perception of risk." *Science*, 236:280-285.

Slovic, P., Fischhoff, B., and Lichtenstein, S. 1985. "Characterizing perceived risk." In R. W. Kates, C. Hohenemser, and J. X. Kasperson, eds., *Perilous progress: Technology as hazard* (pp. 91-123). Boulder, CO: Westview.

Slovic, P., Kraus, N. N., Lappe, H., Letzel, H., and Malmfors, T. 1989. "Risk perception of prescription drugs: Report on a survey in Sweden". *Pharmaceutical Medicine*, 4:43-65.

Slovic, P., MacGregor, D., & Kraus, N. N. 1987. "Perception of risk from automobile safety defects." *Accident Analysis and Prevention*, 19:359-373.

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RISK COMMUNICATION, RECREANCY, AND ORGANIZATIONAL EFFECTIVENESS

Lee Clarke and William R. Freudenburg

INTRODUCTION

We make three points in this paper. The first is fairly obvious: while technical specialists are vital for safely transporting hazardous materials, they are trained to look after their own parts of the picture, in detail, while many important risks of modern technological systems have to do with how those pieces do or do not fit together to make up the whole. The second point you may be less familiar with: much of what is considered "fact" about public views toward science and technology—for example, that the public is ignorant or irrational (and so public relations budgets should be increased)—is based on speculation that, while once plausible, has been proven wrong by a growing body of research.

Our third point may seem paradoxical: while the changing nature of society probably means that you have little choice but to pay more careful attention to public concerns, that may be *good* news, because the characteristics of public views complement those of experts. That is, the public tends to be weak on details, but surprisingly strong on the bigger picture, while experts tend to be strong on technical details, but downright poor on the bigger picture. Perhaps some people have never known an expert who expressed bold confidence in a conclusion that turned out to be completely wrong (often because of some factor that was missing from the expert's theory, training, or field of vision, but vital in reality). For those who have not led such charmed lives, however, there may be some comfort in knowing that the input of the broader public can often be useful precisely because it will highlight the very questions experts often overlook.

Organizations responsible for transporting hazardous materials face an opportunity to help shape national discussions about risk in constructive ways. A nonconstructive response may engender distrust and recriminations; it might also lead to greater hazards for the public. While accidents, even disasters, are inevitable, there are neglected but possibly effective alternative ways to rearrange sociotechnical systems to foster greater safety. There are uncertainties about those alternatives, but that's no reason to avoid them; one must imagine alternatives before they can be possible. In this paper we use some case material, some social scientific evidence, and some general observations to pose nonmainstream ways of thinking about how organizational structure relates to effective risk communication and safety. Our practical suggestions are designed to enhance both risk communication and safety.

A TALE OF TWO TOWNS

Rather than starting with the first point, we want to start with the second one, where the truth is likely to be quite different from what you've heard in the past. What's more, before we get academic about it, we'll be referring to a couple of concrete, real-world examples. The first example may sound familiar to you—in part because it represents a pattern that, until very recently, was something akin to standard operating procedure. The "efficient" management approach to public controversy, many have long believed, has been to damn the torpedoes and sail full steam ahead. We would be remiss if we failed to point out that if a ship actually gets hit by a torpedo, it may not enjoy much forward motion, no matter how much steam is applied.

This point is illustrated by the following case. Lloyd, Florida is a small town about 15 miles east of Tallahassee. As we understand it, four corporations—Texaco, Amoco, Citgo, and Colonial Pipeline—proposed in January 1989 to locate a 6.5 million gallon tankfarm for gasoline and diesel fuel near Lloyd, with a pipeline running to a terminus in Georgia. Texaco has been the major player in the deal. The proposed location is at the intersection of two major roads, thus providing easy access to Tallahassee, a clear benefit of the location. The tankfarm would be in one of the poorest counties in Florida (Jefferson). Estimates are that the project would generate an estimated $80,000 to $99,000 a year in tax revenues and five jobs.

The case developed in the following way. In mid-February 1989, Texaco put a legal notice in a local paper announcing that a public hearing would be held about 10 days later on the rezoning that would be necessary before the tankfarm and pipeline project could proceed. To that point Texaco had sought and received the support of county officials, but in a quiet way that to the public would later appear secretive. There is now considerable protest against the project; petitions, rallies, benefit concerts, and considerable political lobbying are the order of the day. At the risk of sounding flippant, no one involved is happy about the deal.

Let's ask a few basic questions. What are these people worried about? The answer is simple: their property values, their livelihoods, their environment, and their community. They are worried about the Florida aquifer and fires; they are especially concerned about the project's implications for the character of Lloyd, an officially designated historic district. Who are these people? University professors, hippies, blue collar workers, farmers, and poor people of all colors. Such a broad cross-section of people points up the futility of characterizing them as hysterical NIMBYs (people who cry "Not In My BackYard"). What did these people do? The first thing they did was contact Texaco and promise not to oppose the project if the company would move the tankfarm eight miles east to an underused industrial park. Texaco dismissed the protestors, who then began to organize.

Citizens also started doing their homework. It didn't take them long to discover that of the 76 tankfarms in Florida in 1989, 60 had contamination problems on file with Florida's Department of Environmental Regulation. At the rezoning hearing *hundreds* of people showed up (no more than a handful were expected) prepared with information on geology, regulations, topology, emergency response, and chemicals.

It was a very informed group. Another hearing had to be scheduled. In May 1989 the county commission, though initially positive about the project, refused the rezoning request (they would later approve it). But that was not the end of the story. Texaco responded with another plan that would move the tankfarm only 400 yards from the original proposed site and mounted a public relations (we're tempted to say "risk communication") campaign. Television adds appeared with personal attacks on local protest leaders. A small army of lobbyists went to work on local and state legislators. The consultants and lawyers appeared, local organizations started receiving corporate donations, television and radio commercials cropped up. A typical commercial message:

> The world has always had its share of alarmists. Remember Chicken Little? That simple bird thought the sky was falling. It seems that whenever someone suggests change, the alarmists band together to denounce progress.

It is hard to conceive of a more ineffective way to communicate about risk. (We should note that Colonial Pipeline, Texaco, and others in favor of the tankfarm view the issue primarily as one of economic development. In any case, in February 1992, after millions of dollars and great energy expended by all concerned, a federal court ruled against the pipeline, though Colonial says "it's not a dead issue.")

That's the bad news. But, we hasten to point out, it doesn't have to be this way. As the following case illustrates, a little *perestroika* goes a long way toward enhancing risk communication and, not incidentally, safety itself.

There is a corporation in New Jersey, a chemical plant of all things, that has the trust of the community it is able to make sick.[1] Relations were not always so cozy. A few years ago the plant was in the middle of a crisis because a series of management errors and technical breakdowns caused some hazardous materials releases, fires, and serious injury to workers. What happened in the meantime? The corporation (and there are other examples) instituted a far-reaching review of its training and personnel practices. It sunk time and money into upgrading safety equipment in the plant, with advice from experts. It established a permanent committee of citizens and plant personnel to review safety procedures, risk communication programs, and future expansion plans. It created a variety of early warning systems that included people in the community. In short, the corporation entered into a meaningful partnership with the community, responding to community concerns in concrete ways, rather than mere public relations campaigns (although the company did win an award from the Public Relations Society of America).

That case demonstrates, among other things, that when the public is part of organizational decision-making processes, risks can decline and risk communication can increase. Studies of decision making and studies of organizational learning

1. This story is from research conducted by Caron Chess, Alex Saville, Michal Tamuz, and Michael Greenberg (1992), "The Organizational Links Between Risk Communication and Risk Management: The Case of Sybron Chemicals, Inc." *Risk Analysis* 12 (3, Sept.): 431-38.

suggest that one of the key mechanisms to help reduce risk is, in a word, argument.[2] The general principle is that soliciting and considering multiple perspectives on potential problems raises alternatives that might otherwise be overlooked. Concretely, the principle means greater control over risks and enhanced risk communication. No one completely understands sociotechnical systems, even fairly simple ones. This fact suggests the problem of uncertainty, especially uncertainty about predicting the future. We know that experts tend to focus fairly narrowly on what they are expert about. We know that organizational cultures and interests also narrow the kinds of things it is considered legitimate to think about. The New Jersey case demonstrates that in the long run, social conflict enhances organizational effectiveness in anticipating and responding to hazards, but only if that conflict is brought into the decision-making process rather than shunned as a problem.

UNDERSTANDING PUBLIC REACTIONS

While case studies provide only a partial picture, there is growing evidence from the literature that these two case studies represent broader trends. While it was once widely believed that public concerns about technological developments were based largely on ignorance or misinformation, and thus that the problems could be overcome by "public education" (or in more recent years, by "risk communication"), it now appears that this widespread belief had everything going for it except the facts.

First of all, a variety of studies have found that public opponents of technologies tend to be just as well informed as the supporters (see, e.g., Dunlap and Olsen, 1984; Gould et al., 1988; Mitchell, 1984; Rosa and Freudenburg, 1984; for a thoughtful review, see Dietz et al., 1989; see also Johnson and Covello, 1987; Kraft and Clary, 1988; Kasperson, 1986; Fiorino, 1989). In fact, a growing number of site-specific studies have found that *supporters* make up their minds very early, and have little interest in new factual information while *opponents* actively search for new information (Fowlkes and Miller, 1987; see also Edelstein, 1988; Freudenberg, 1984; Freudenburg, 1993; Krauss, 1988; Kroll-Smith et al., forthcoming; Levine, 1982).

Second, as Mazur (1981) predicted a decade ago, although public information campaigns have achieved impressive successes in selling everything from cigarettes to pet rocks, many of their most noteworthy failures have been in trying to convince the public that technological systems are acceptably safe. For instance, at the aggregate level, it is worth noting that attitudes toward nuclear power have become far more negative in recent years, and that this change has taken place after many years of public relations efforts, both private and governmental, designed to have just the opposite effect. Rremember the massive PR campaign about "my friend, the atom," in the 1950s and 1960s? Remember the public backlash against nuclear power in the 1970s and 1980s?.

Even when we turn our attention to risk communication efforts focused on more

2. James G. March, Lee S. Sproull, and Michal Tamuz, "Learning from Samples of One or Fewer," *Organizational Science,* 1991, 21(1):1-14.

specific technologies, such as nuclear waste repositories, the experience is scarcely reassuring to anyone who believes that cherished delusions are less persuasive than actual facts. In the United States, opposition has continued to mount, even in Nevada, where the U.S. Department of Energy (DOE) has spent over a billion dollars on studies designed to demonstrate the safety (and the local economic benefits) of a proposed high-level nuclear waste repository; an industry group has invested millions more on "risk communication efforts" intended to reduce such opposition. DOE's lack of success, notably, has been in a state where surveys suggest that the population has lower levels of environmental concern than are found in the population as a whole, and where, after all, the concept of "risk" is scarcely a foreign one (Kunreuther et al., 1988; Slovic et al., 1990). Even in Asian countries, to make a brief international comparison, that are commonly seen as being far more deferential toward science and technology than is the case in this country, studies have found that, if anything, official assurances about the safety of proposed nuclear waste facilities make citizens more suspicious (Liu and Smith, 1990; Budd et al., 1990; United Press International, 1990).

Third, evidence is mounting that what is important in risk perception, and hence risk communication, is less the characteristics of the individual "perceivers" and more the *institutional actors* who are being perceived. When salespeople make their best pitch but the customers just aren't buying, they may be tempted to conclude that there's something wrong with the *customers*. But eventually, if repeated efforts fail, they may have to consider the alternative hypothesis: maybe something is wrong with the salesperson, the product, or the sales pitch. Similarly, recent studies have been converging on the conclusion that crucial factors in risk perception have to do with the trust and credibility enjoyed by those who are responsible for managing science and technology. Indeed, we know from years of research on natural hazards and recent work on technological hazards that people care deeply about social disruption. We also know that such disruption is often dismissed as being only about risk perception, as if such troubles were not real. Such concerns are indeed hard to quantify, which is one reason formal risk assessments never take social disruption into account, but that is a poor reason for excluding them in organizational decision making. That is, research shows that people care about *how* risky decisions are made: Are they made fairly? Who's interests are served? Why this decision and not another? Who has assumed authority in the situation?[3] In other words, people care about threats to the "social fabric."[4]

Freudenburg (1993) discusses the topic in terms of "recreancy," or the failure of institutional actors to carry out their specialized duties with the degree of vigor necessary to merit the societal trust they enjoy. To understand the concept's importance, reflect for a moment on what it means to say that we live in an advanced,

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3. See especially Steve Rayner and Robin Cantor, "How fair is safe enough? the cultural approach to social technology choice," *Risk Analysis*, 1987, 7(1):3-9.

4. James F. Short, Jr., "Toward the social transformation of risk analysis," *American Sociological Review*, 1984, 49(6):711-755.

technological society. In at least one important respect, it does not mean that we "know more" than did our great-great-grandparents. Collectively, of course, we do know far more, but individually, we tend to know far less about the technology we depend on every day. Instead, we "depend on" the technology to work properly. More important, we also depend on people and organizations to perform their specialized tasks with an extremely high level of reliability, competence, and trustworthiness. Our great-great-grandparents had almost none of the technology that helps us today, but in general, they could make or repair by hand almost any of the technology upon which they depended. Today, we have access to far more technology, and we enjoy lives that are both longer and more prosperous because of it. In the process, however, modern societies are far more interdependent, and far more vulnerable to institutional actors whose job performance is lacking, whether in competence, in dedication, or even simply in breadth of vision.

THE LIMITS OF EXPERTISE

This brings us back to our first point—experts excel in understanding the pieces of a system, but tend not to excel in understanding the whole. The breadth-of-vision issue is a particularly important one, but it is also perhaps the least obvious one, particularly for persons who are technically trained.

Perrow (1984) defines an "expert" as someone who can solve a problem far more efficiently and quickly than could a "normal" person, but who runs a far greater risk of asking the wrong question altogether. A more widespread definition is that an expert is someone who knows more and more about less and less. To be a bit less flippant, expertise is a special kind of double-edged sword. Specialization is a major part of the value of expertise, in that it allows someone to focus so intently on one small slice of the universe as to become an "expert" on it. At the same time, however, that narrowness may hinder effective comprehension of the wide array of risk-issues that go along with technological systems.

Perhaps nowhere does this come through as clearly as in technological organizations that need to combine specialized expertise, efficiency of operation, and the avoidance of catastrophes. Specialization can be useful both in bringing in the necessary expertise and, under most circumstances, in improving the efficiency of operations, particularly where those operations are relatively routinized. But for the successful management of risks and avoidance of disasters, particularly in undertakings such as the transportation of hazardous materials, the sword's other edge is also relevant. While individual specialists might be able to avoid a certain amount of responsibility with the age-old battle-cry of "that's not my department," one of the responsibilities of system managers is precisely to assure that important or "fatal flaws," no matter whose "department" they properly belong to, do not fall through the cracks.

We want to push this point a little further. Arguments about risk communication often revolve around talk of irrational publics, emotion-driven reactions, NIMBYs, and so on. Unfortunately, these terms are more epithets than useful ways to frame discussions. Much of this finger wagging is inspired, though not motivated, by the pioneering work of cognitive psychologists Amos Tversky and Daniel Kahneman on one hand and Paul Slovic and his colleagues on the other. It is intellectually shameful that their work has been so corrupted; it is also dangerously wrong to interpret their important research as evidence of public foolishness.

A major contribution from cognitive psychology is to show how individuals' rationalities diverge from those of a highly stylized, very abstract rational economic actor.[5] Put differently, work on heuristics and the cognitive categories people use to make sense of risks reveals the complexity and ambiguity of human decision making. Psychology's most interesting contribution on risk is to show how people are, in the words of Nobel laureate Herbert Simon, "boundedly rational" in their confrontations with risk.

The idea of bounded rationality captures decision making processes under constraints: on attention, memory, and comprehension of problems and environments. Oddly, and to the great detriment of organizational behavior regarding risk communication, the origins and original applicability of Simon's insight have been ignored. Since Simon we have known and researched how organizations and their participants make systematically biased choices. The term "their participants" refers to decision makers and support personnel alike. Interestingly, although all work on bounded rationality can be interpreted as highlighting human imperfections, the research has not derogated those who are boundedly rational; nor has the research been so used outside intellectual circles. While work on bounded rationality demonstrates how organizations induce bias, it does not impute dubious motives to the actual people it studies. Rather, emphasis is placed on organizational structures and demands in organizational environments. Yet when the same discussion is about people not directly connected to formal organizations—another name for "the public"—a different story emerges, one with a dismissive tone and sometimes thinly veiled condescension. It has become a cottage industry to complain that risk perception is where all the action is. The implication is that only if people knew the real risk they wouldn't be so unreasonable. But if the charge that it's all perception is true for the public, then it is also true for decision makers.

THE GOOD NEWS

Given that this paper has included a fair amount of information that many risk specialists find depressing, even if important, perhaps it's more important than usual that we follow the old advice about ending on an upbeat note. Fortunately, an upbeat note is easy to find, and it just happens to be the last of the three points we mentioned at the start. While taking public (and worker) concerns seriously may not be easy, it is likely to be rewarding—not just in terms of improved public relations, but also in terms of improved safety of operations.

In 1989 the 3M corporation installed $26 million worth of equipment that burns

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5. This work has been troubling to economics, but that's not our topic here.

waste solvents from two chemical plants in Minnesota. But it didn't have to. The 3M plants were already meeting EPA standards for airborne effluents, but 3M considered those standards too weak, as environmentalists often conclude of EPA standards. 3M's payoff for doing more? Perhaps it is too early to tell, but Barry Commoner—an adamant environmentalist to say the least—had this to say: "They are one of the few companies that have been doing the right thing for years."[6] Commoner added, "They understand that the way to prevent pollution is to eliminate the production of toxic materials." The town is happy, environmental groups are happy, workers are happy, the company is happy. 3M has discovered that environmentalism can be profitable.

Notably, 3M achieves its safety goals not by the usual array of solutions: better training, better public relations, perhaps a ceremonial program or two. Rather, the program works because 3M embeds into the production process regular upgrading of technologies with environmentally sound designs. 3M also retrofits older plants, in increments, with the goal of achieving a 75% reduction in effluents before the year 2000. 3M also instituted a cleanup program before governments forced them to do it, allowing more flexible development and on terms best suited to the company.

3M's behavior, incidentally, defies standard economic theories (which say corporations will create negative externalities unless commanded to do otherwise), as well as the oft-heard slogan that "it will drive us to third-world countries." Note that 3M's management is no more friendly to regulation than we would expect any corporation to be. 3M managers do, however, approach the "regulatory burden" in an unusual way. "If we get rid of the pollution," says a 3M vice president, "we get out from under the regulations."[7] The company estimates a savings of one-half billion dollars from environmental innovations since 1975, and it is strong on Wall Street.

The 3M case illustrates two deficiencies in how scholars and decision makers talk about risk communication. We'll be blunt. The term "risk communication" often means manipulating organizational images about safety, whether those images are true or not. Too much risk communication is simple sloganeering or complex advertising, neither of which are conducive to real communication. Worse, when risk communicators get beyond simple public relations, they often adopt the "California therapy solution," which ultimately does not foster trust but rather elicits cynicism from the public. The California therapy solution ("Let's talk about it") assumes that the main barrier to consensus around an issue is an unwillingness or inability to take the other's view. The logic is that if only people would sit down together for honest interchange, social conflict would subside.

The trouble with such a view is that, if you will excuse an excess, it's all talk and no action. The truth is that people (and organizations) often have conflicts of interest that are structurally rooted, and no amount of talk can make those conflicts vanish. That this is so suggests the importance of going beyond talking cures to more lasting, structural solutions to risk problems (including problems of risk communication). *That* is the key to 3M's success.

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6. The 3M story comes from John Holusha, "Hutchinson No Longer Holds Its Nose," *New York Times*, 3 February 1991, Section 3 p. 1+.

7. Ibid.

THINGS TO INCREASE EFFECTIVENESS

We end with some lessons for risk communication:

1. Avoid Irrelevant Comparisons and Condescension

Don't tell people the risk of a major accident is less than being struck by lightning. It is not an appropriate comparison for two reasons. First, one risk cannot be traded for the other, so they are incommensurable risks; i.e., risks that have no common standard of comparison.[8] Second, they are not about the same thing because one is imposed and the other is random. As a Greenpeace campaigner put it in a discussion about incinerators:

> It would be more fair if you compared the danger of living next to a toxic waste incinerator to the risk of being struck by lightning if someone kidnaps you during a thunderstorm, takes you to an open field and ties you to a giant metal pole.[9]

Dismissive, condescending public relations campaigns are insulting, and insulted people don't like you, and people who don't like you don't trust you. Respect the community. Work with community members, not just the leaders. Also, kill the cliches and threats like: "driving a car is more dangerous than X," "life is a risk," "we're trying to avoid public panic." If corporate managers said to a loan officer some of the things some corporate representatives say to communities, they'd be fired on the spot. Corporations don't operate on cliches and slogans, and the public knows that. The public doesn't operate on them either.

2. Suspect Formal Risk Assessments

A corollary to lesson one is not to rely heavily on formal risk assessments in either decision-making processes or in dealing with the public. No risk assessment is value-free and people know that. We aren't saying formal assessments are cynically produced documents, used in an evil manner to dupe the public. But such assessments inevitably adopt assumptions—about the value of life, community, and especially difficult to measure things—that are open to legitimate disagreement. Different assumptions reflect different interests. We live in a time when people are increasingly sophisticated about science and experts. They may not know the details, but they do know experts can be wrong. They know about conflicts of interest, and they have

8. Lee Clarke, "Politics and bias in risk assessment," *Social Science Journal*, 1988, 25(2):155-165.

9. Joe Thorton, "Risk in democracy," *Greenpeace* Mar/Apr 1991, p. 18.

responded with distrust. Effective risk communicators will assume that distrust has a basis that should be respected, rather than dismissed. They also know that risk acceptability is always a question about "acceptability to whom?"

3. Don't Hide Conflict

Organizations often present a unified, certain face to the public that hides conflict, uncertainty, political judgments, and the value choices inherent in decisions about risk. But people know such things exist—after all, almost everyone works in organizations—and so distrust those who claim they don't.

4. Engage in Partnerships, Not Just Communication, by Building Structural Connections with the Public

The Oil Pollution Act of 1990 says "one way to combat . . . complacency is to involve local citizens in the process of preparing, adopting, and revising oil spill contingency plans" and "only when local citizens are involved in the process will the trust develop that is necessary to change the present system from confrontation to consensus." These are high moral positions, and Congress did not go further to mandate or even suggest concrete reforms. But it is good advice.

Rather than public relations, let us change sociotechnical systems. Organizations should approach risk communication less as a matter of educating children and more as one of making joint ventures (in which safety can be profitable). It is generally the case that there is a lack of structural connections between corporate decision making and concerned publics—mainly relevant environmental groups and communities—i.e., those without concrete mechanisms that would connect them with important centers of decision making, at least without going through other agents who have interests of their own, such as media and government.

Changing organizational structures to foster better risk communication and greater safety includes changes such as the following:

a. Establish a risk communications department, guided by three main principles: 1) no one with formal public relations training should allowed to head the department, 2) *every* organizational member who will be communicating with the outside should spend two months as an intern, and 3) the department head should be at the level of vice president.

b. Institute mechanisms that encourage, not just tolerate, *internal* whistle blowing and disagreement.

c. Institute a standing, rotating committee of insiders and outsiders to review safety programs and institute new ones.

REFERENCES

Budd, William, R. Fort and Robert Rosenman. 1990. "Risk Externalities, Compensation and Nuclear Siting in Japan." *The Environmental Professional* 12:208-13.

Chess, Caron, Alex Saville, Michal Tamuz, and Michael Greenberg. 1992. "The Organizational Links Between Risk Communication and Risk Management: The Case of Sybron Chemicals, Inc." *Risk Analysis* 12 (3, Sept.): 431-38.

Clarke, Lee. 1988. "Politics and bias in risk assessment." *Social Science Journal* 25(2): 155-165.

Dietz, Thomas, Paul C. Stern and Robert W. Rycroft. 1989. "Definitions of Conflict and the Legitimation of Resources: The Case of Environmental Risk." *Sociological Forum* 4(1): 47-70.

Dunlap, Riley E. and Marvin E. Olsen. 1984. "Hard-Path Versus Soft-Path Advocates: A Study of Energy Activists." *Policy Studies Journal* 13:413-428.

Edelstein, Michael. 1988. *Contaminated Communities.* Boulder: Westview Press.

Fiorino, Daniel J. 1989. "Technical and Democratic Values in Risk Analysis." *Risk Analysis* 9 (3, Sept.):293-99.

Fowlkes, Martha R. and Patricia Y. Miller. 1987. "Chemicals and Community at Love Canal." Pages 55-78 in Branden B. Johnson and Vincent T. Covello, eds., *The Social and Cultural Construction of Risk: Essays on Risk Selection and Perception.* Dordrecht, Holland: D. Reidel.

Freudenberg, Nicholas. 1984. "Citizen Action for Environmental Health: Report on a Survey of Community Organizations." *American Journal of Public Health* 74: 444-48.

Freudenburg, William R. 1984. "Boomtown's Youth: The Differential Impacts of Rapid Community Growth Up on Adolescents and Adults." *American Sociological Review* 49 (5, October):697-705.

Freudenburg, William R. 1993. "Risk and recreancy: Weber, the division of labor, and the rationality of risk perceptions." *Social Forces*, Vol. 71.

Gould, Leroy C., Gerald T. Gardner, Donald R. DeLuca, Adrian R. Tiemann, Leonard W. Doob and Jan A. J. Stolwijk. 1988. *Perceptions of Technological Risks and Benefits.* New York: Russell Sage.

Holusha, John. 1991. "Hutchinson No Longer Holds Its Nose." *New York Times*, 3 February 1991, Section 3 p. 1+.

Johnson, Branden B. and Vincent T. Covello, eds. 1987. *The Social and Cultural Construction of Risk: Essays on Risk Selection and Perception.* Dordrecht, Holland: D. Reidel.

Kasperson, Roger E. 1986. "Six Propositions on Public Participation and Their Relevance for Risk Perception." *Risk Analysis* 6 (3, September): 275-281.

Kraft, Michael and Bruce B. Clary. 1988. "Assessing Citizen Participation in Environmental Policy: The NIMBY Syndrome and Radioactive Waste Disposal." Presented at Annual Meeting of American Political Science Association.

Krauss, Celene. 1987. "Community Struggles and the State: From the Grassroots—A Practical Critique of Power." Presented at the American Sociological Association Annual Meeting. Chicago, August.

Kroll-Smith, J. Stephen, Stephen R. Couch and Adeline G. Levine. Forthcoming. "Technological Hazards and Disasters." Forthcoming in Riley E. Dunlap and William Michelson (eds.), *Handbook of Environmental Sociology*. Westport, Conn.: Greenwood.

Kunreuther, Howard, William H. Desvousges and Paul Slovic. 1988. "Nevada's Predicament: Public Perceptions of Risk from the Proposed Nuclear Repository." *Environment* 30 (8, October): 16-20, 30-33.

Levine, Adeline. 1982. *Love Canal: Science, Politics, and People.* Lexington: D.C. Heath and Co.

Liu, J. T. and V. Kerry Smith. 1990. "Risk Communication and Attitude Change: Taiwan's National Debate over Nuclear Power." *Journal of Risk and Uncertainty* 3:327-45.

March, James G., Lee S. Sproull, and Michal Tamuz. 1991. "Learning from Samples of One or Fewer." *Organization Science* 21(1): 1-14.

Mazur, Allan. 1981. "Media coverage and public opinion on scientific controversies." *Journal of Communication* 31:106-115.

Mitchell, Robert C. 1984. "Rationality and Irrationality in the Public's Perception of Nuclear Power." Pp. 137-179 in William R. Freudenburg and Eugene A. Rosa, eds., *Public Reactions to Nuclear Power: Are There Critical Masses?* Boulder, CO: American Association for the Advancement of Science/Westview.

Perrow, Charles. 1984. *Normal Accidents.* New York: Basic Books.

Rayner, Steve and Robin Cantor. 1987. "How fair is safe enough? the cultural approach to social technology choice." *Risk Analysis* 7(1): 3-9.

Rosa, Eugene A. and William R. Freudenburg. 1984. "Nuclear Power at the Crossroads." Pp. 3-37 in William R. Freudenburg and Eugene A. Rosa, eds., *Public Reactions to Nuclear Power: Are There Critical Masses?* Boulder, CO: American Association for the Advancement of Science/Westview.

Short, James F. Jr. 1984. "Toward the social transformation of risk analysis." *American Sociological Review* 49(6): 711-755.

Slovic, Paul, Mark Layman and James H. Flynn. 1990. "What Comes to Mind When You Hear the Words, 'Nuclear Waste Repository'? A Study of 10,000 Images." Carson City, Nevada: Nevada Nuclear Waste Projects Office.

Thorton, Joe. 1991. "Risk in democracy." *Greenpeace* Mar/Apr p. 18.

United Press International. 1990. "Islanders Protest Construction of Nuclear Waste Storage Facility." New York: United Press International News Wire Story, Nov. 8.

14

RISK, LOSS AND LIABILITY IN THE TRANSPORTATION OF HAZARDOUS MATERIALS

Marshall S. Shapo

INTRODUCTION[1]

This paper analyzes the theories of liability that are relevant to the business of transporting hazardous materials. I shall set those theories in their functional environment, of which they are creatures, and shall also describe them against the background of the policies that undergird them. I shall then explore the implications of liability rules for transportation of hazardous materials, and conclude with some observations, relevant to the particular subject, on the role of liability rules in society.

With specific reference to practical concerns, I will discuss the well-established theory of negligence and also the theory of strict liability for abnormally dangerous activities, which is now in a process of evolution in our courts. I shall refer also to the old workhorse of the law known as nuisance. As an overlay to that discussion, I will counterpose two rationales for our law of injuries, both of which are intuitively familiar to business persons and citizens. These sometimes conflicting rationales are rooted in moral considerations and in efficiency justifications.

INJURY LAW AND ITS FUNCTIONAL BACKGROUND

Having begun academic life as a torts teacher, I now have come to think of my field of study as "injury law," the collection of rules, doctrines and policies through which the legal system deals with the problem of injuries. This body of law is complex. In part, it consists of the rules generally called "tort" and of a vast and often technical set of regulatory statutes. It also includes a diverse group of laws that provide, in various ways, for the payment of compensation for injuries without specific inquiry into fault or the relative degree of danger of the activity that caused the harm. My focus in this paper is on doctrines of tort law, the rules that govern private suits for injury against people or firms on the basis of their alleged culpability or the especially dangerous character of their activities or products.

Those doctrines have arisen principally from the responses of courts to

1. I am grateful to Jay Hillman, professor emeritus, Northwestern University School of Law, for his many constructive suggestions.

particular cases. Filtered through a sophisticated procedural process, they represent society's legal reaction to the question of what constitutes proper allocation of risk and loss.

Risk

Because it is discussed in a number of other papers in this volume, I need spend very little time on the functional root of all tort law, the fact of risk. There are various technical and lay definitions of the concept, but for our present purposes, the definition that appears in any basic insurance text is a good beginning point: Risk is uncertainty about loss.[2] When we speak of risk in this context, we are speaking of multiple tiers of uncertainty. We are uncertain not only about whether certain kinds of events—for example chemical spills—will occur, but also about the effects of those events. Moreover, our lack of ability to make specific predictions about consequences extends both to causation and to actual losses.

I also should note that in a world in which toxic substances multiply in response to thousands of human wants, a parallel kind of uncertainty afflicts entrepreneurs: a perceived inability to predict the particular application of legal standards. I am not making value judgements here; I am simply describing what I take to be a concern of many business persons. Yet, given the sophistication and the level of hazard of many of the products at issue, it is not surprising that uncertainty in the law should parallel uncertainty about the frequency and severity of injury-causing events. I should tell you, at the risk of being treated like the Greeks treated the bearer of unwelcome news, that in my conclusion I will have to inform you that you must continue to expect a fair amount of uncertainty in judicial decision making on these issues.

It is appropriate here, by way of synthesizing the intellectual framework of a part of this volume, to make reference to the principal set of ways in which business persons deal with risk: insurance and related risk-pooling mechanisms. Without detailed summary of the facets of insurance that are relevant to the perspective of the tort lawyer, I will simply emphasize some basic considerations. Insurers must be able to use statistical tools, based on an assumed regularity of the occurrence of large numbers of events, in order to determine the probabilties of those events. They must be able to make predictions about probability in order to set premiums that will allow them to reduce their policyholders' individual risks. Consequently, they must look to the law for relative degrees of certainty and predictability in liability regimes.

Loss

Loss is the terrible sibling of risk. When the hazard becomes a reality, we have loss; when liability rules compel one person to pay for another's loss, we refer to

2. See, e.g., R. Mehr, E. Cammack & T. Rose, Principles of Insurance 19 (8th ed. 1985).

damages. Many problems, both theoretical and practical, reside under this heading of tort law. A Canadian commentator has gone so far as to say that there is an "absence of coherent principle in the law of damages for personal injuries."[3] At the least, there are plenty of competing theoretical models on which to ground the award of tort damages.[4]

The bitterness of the controversy over various elements of damages is evident in the diametrically opposed thrusts of current arguments among tort theorists and tort politicians. On the one hand are the forces of those who would curtail, or even eliminate, "noneconomic damages," principally pain and suffering. On the other hand, plaintiffs continue to advocate expanded conceptions of the appropriate categories of damages--from loss of ability to enjoy life to fear of a disease that may never occur.

CONTROVERSIAL PREMISES

The disputes I have just mentioned are only symptomatic of the rich arguments that permeate the field of torts. Fittingly for a subject so entwined with our conceptions of dignity and the value of life and limb, those arguments extend to the very premises of the award of civil damages for injury. I should add that though many of you may be more concerned with property loss than with personal injury, tort law tends to equate those two items of damages, as contrasted with purely economic loss.

Behavioral Premises

An important set of controversies relates to the assumptions that judges and lawmakers make about the way people perceive situations and the way they act under particular legal regimes. I aim here to describe how tort doctrine calculates, and responds to, the abilities of human beings to perceive and deal with risk.

Perceptions. Every person brings to any situation a considerable train of biological, intellectual and emotional baggage. These mental elements color each person's perceptions of any profile of risk that he or she may encounter. They may affect the behavior of those who conduct hazardous activities and those who are at risk from those activities.

First, one's mental conditioning will affect how he or she perceives the degree of

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3. McLachlin, What Price Disability? A Perspective on the Law of Damages for Personal Injury, 59 Can. B. Rev. 1, 1 (1981).

4. For a summary of several approaches, see Towards a Jurisprudence of Injury: The Continuing Creation of a System of Substantive Justice in American Tort Law 5-165 - 5-166 (ABA 1984 M. Shapo Rptr.).

risk in a particular situation. This perception will be a function of such things as intelligence, expertise and practical experience. These qualities may affect decisions on whether to consider actors culpable and whether to hold that injured persons should have taken better care of themselves. The most general rule that the law of torts applies to questions of this sort is one that holds everyone to an objective standard,[5] and that rule has been applied with seeming harshness to plaintiffs charged with contributory fault[6] as well as to defendants alleged to be negligent. Yet sometimes the law makes allowances for the inability of certain classes of persons to judge risk; children are a principal beneficiary of subjective tort standards, at least when they engage in activities typical of persons their age.

Attitudes toward risk. A different, but related point relates to attitudes toward risk. Anyone who has achieved puberty has at least an intuitive feel for the fact that different people have very different attitudes toward the chanciness of life. Some are "risk preferrers" and others are relatively averse to risk. Doubtless these characteristics have many roots—in the genes, in home atmospheres, in personal experiences. The point is that, at some level, every tort decision deals with at least one person's attitude toward risk, as well as with society's view of what risks are worth taking. Certainly a major principle of tort law is that people should indulge their risk preferences on their own time, so to speak, and not at the expense of others.

At the same time, much of our law makes allowances for a recognition that our progress as an economy relates in part to our willingness to take risks. This is evident, for example, in judicial approval of the idea that "under some conditions there should be no liability for certain very useful products, such as drugs and vaccines, 'which, in the present state of human knowledge, are quite incapable of being made absolutely safe for their intended and ordinary use.'"[7] That is the formulation of comment k of section 402A of the Second Restatement of Torts, which features in its comments an elaborate definition of the concept of defect in products liability law.

Effects of the law on conduct. When we look into the relationship between law and behavior, we must consider how they influence each other. Certainly law arises from society's reactions to human conduct. The rationale for various standards of conduct in tort law, for example, emerges from our observations, over a long baseline, of how people in fact behave; this data gives us a feel for how they should behave, in part because it is a pretty good indicator of their capabilities. These observations relate further to what I shall say presently about the normative aspects of law.

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5. The most famous decision is the nineteenth century English case of Vaughan v. Menlove, 3 Bing., N.C. 468 (C.P. 1837).

6. See, e.g., Wright v. Tate, 208 Va. 291, 156 S.E.2d 562 (1967).

7. M. Shapo, The Law of Products Liability, ¶ 8.04[7][a] at 8-13 (1990), quoting Restatement (Second) of Torts § 402A, comment k (1965).

A crucial consideration relates to the other side of the coin: what is the effect of law on conduct? A host of safety statutes, including the Hazardous Materials Transportation Act, testifies to a collective belief that law, and rules of law, are capable of regulating conduct. We have a substantial amount of evidence, but also a great deal of uncertainty, about the effects of both judicial and regulatory rules.[8] Despite the uncertainty, the rise of a profession of risk management, and the constant reference in a variety of trade journals to the liability climate, are indicators of the impact that law has on behavior. Perhaps the most striking encapsulation of this apparent truth appears in a Rand Corporation report on the reactions to the legal environment of corporate officials whose jobs included a focus on product safety. The authors of that study indicated that although the signal sent out by judge-made rules on products liability is "extremely vague," it also exerts "powerful" influence. The message that these investigators deciphered was, " 'Be careful, or you will be sued.' "[9] For our present purposes, it seems safe to assume that the newly amended statute on hazardous materials transportation will have significant effects on conduct, as will the applicable judge-made rules, which I will analyze below.

The Normative Aspects of Law

Much of the academic literature in vogue in tort law today takes as the alpha and the omega of analysis the question of whether particular rules will be conducive to economic efficiency. Yet an older tradition, and one that is likely to continue to have a powerful hold on the intuitions of judges, lawyers and ordinary citizens is one that emphasizes the normative aspects of tort law. The proposition is a simple one: actors should pay for injuries caused by conduct or products that present unreasonable danger to others.[10] The "should" idea connotes a sense of moral rightness. There is, to be sure, a literature that suggests that judicial decisions reflect at least a subconscious commitment to efficiency,[11] and sometimes what ought to be done is what is likely to prove efficient. But I believe most judges, and most nonlawyers, would subscribe to the proposition that concepts like "negligence" and "unreasonably dangerous product" basically reflect a judgement about social norms.

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8. See generally Towards a Jurisprudence of Injury, supra note 3, Chapter Nine.

9. G. Eads & P. Reuter, Designing Safer Products: Corporate Responses to Product Liability Law and Regulation viii (Rand, R-3022-ICJ, 1983).

10. Cf. Keating, J., dissenting, in Riss v. City of New York, 22 N.Y. 2d 579, 590, 240 N.E.2d 860, 865, 293 N.Y.S.2d 897, 905 (1968) (tort law "sets forth standards of conduct which ought to be followed").

11. See, e.g., Posner, A Theory of Negligence, 1 J. Legal Studies 29 (1972).

The Concept of Market Experimentation

At this point, I want to introduce a concept that is relevant to both the behavioral and moral premises that I have just discussed. This is the idea of "market experimentation"—"the ongoing inquiry into hazardous effects, using members of the general public as subjects, that is a necessary part of the conduct of new activities and the marketing of new products."[12] This label, I must emphasize, is not pejorative. It is descriptive. It recognizes that every time a chemical manufacturer puts out a new product, every time an auto maker places a new model on the roads, every time I make a soup from scratch in the kitchen at home, consumers are serving as subjects in a process of data collection. That process produces better chemicals for better living, more splendid vehicles, and more excellent soups. A byproduct, however, is a substantial number of injuries and illnesses.

The law straddles the process of market experimentation to incorporate our observations of entreprenurial behavior and our judgements of when those who conduct these experiments should have to pay their often unknowing subjects. This observation applies to such activities as the transportation of hazardous materials as well as the manufacture of products. Any time that a transporter uses a new technology, or tries new procedures for carriage, it is engaged in market experimentation. I reemphasize that this statement constitutes an observation, and not a judgement. It is the law that makes judgements about what kinds of experimentation are proper subjects for liability.

POLICY GOALS OF THE LAW

What I have just said leads me to a discussion of the goals of the law, particularly of that branch of injury law we call torts. Sometimes courts articulate those goals accurately and clearly. On other occasions they may not choose to do so, or their efforts to articulate them serve as masks for other ideas. In the latter cases, we must dig down to the true policy roots of judicial decisions. I shall describe briefly some of the major goals and principles that appear to govern judicial response to tort cases.

Compensation

A fundamental goal of tort law is to compensate persons who have sustained loss because of conduct or products that have violated judicially set standards, including standards derived from legislation and administrative regulation. It is an academic truism that if we were interested only in making up for the loss of income or capital attributable to an injury, we would not use a system of personal injury litigation to do that. For example, we could compensate people disabled by personal

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12. M. Shapo, A Nation of Guinea Pigs xiv (1979).

injuries more efficiently through something like a social security system rather than by a process that relied on pleadings, an adversarial mode of fact-finding and a set of rules designed to sift through conflicting assertions about culpability and related concepts.

Yet compensation has been an important feature of tort approaches to injury for centuries. In significant measure, this is because tort law ties compensation to the act or the product or process that caused the loss. The great torts scholar Leon Green got to the root of this idea with his succinct reference to "a deep sense of early common law morality that one who hurts another should compensate him."[13] This moral basis for compensation, I suspect, bulks large in the minds of judges and jurors when they consider whether to impose liability on defendants for injuries attributable to activities that are, by definition, quite dangerous.

Deterrence

The desire to compensate injured persons exists in uneasy harness with another principal set of tort law goals: deterrence. Every nonlawyer has an intuitive sense that one reason for setting standards of conduct is to regulate behavior, and specifically in the area of law with which we are dealing, to reduce accidents.

A serious question of legal policy now arises: to what level do we want to reduce the frequency of injurious occurrences? For economists, the answer tends to be characteristically technical: the proper level of accidents is the one that produces efficient results. The definition of efficiency has many shadings, but for our present purposes it will suffice to say that an efficient market is one that facilitates the purchase of the bundles of risks and benefits that properly informed, competent consumers would freely choose.

Negligence law, at least, invokes the standard of the reasonable person. Who is this reasonable person? Economic theory reasons this way: it is the person who calculates accident costs and accident avoidance costs, and spends up to, but only up to, the amount where accident avoidance costs do not exceed accident costs. To spend more would be inefficient, and that would be uncharacteristic of reasonable persons.

Courts, on the whole, have tended to take a more flexible view of the matter. This may be because courts have to deal directly with injured people. They must witness films of previously healthy, active persons lying in hospital beds or trying with heartbreaking effort to perform the simplest task. At every step of the litigation process, they have to take into account factors that tend to confound, or at least complicate, the more facile assumptions of efficiency analysis. These factors include not only the difficulties of calculating noneconomic damages, but also the transaction costs of litigation itself.

Reacting to these complicating factors, courts have tended to cast deterrence in

13. L. Green, Foreseeability in Negligence Law, 61 Colum. L. Rev. 1401, 1412 (1961).

different terms than do economic analysts. A typically strong presentation of this type of deterrence position appeared in a Delaware decision that imposed strict liability against a truck rental company. The court in that case said that "[t]he present-day magnitude of the motor vehicle rental business, and the trade practices which have developed therein, require maximum protection for the victims of defective rentals."[14] In some cases, judicial declarations of this sort may not necessarily be incompatible with an efficiency analysis, but the thrust is very different. Rather, this sort of language reflects a "general commitment to the idea that the rate of injuries in a particular activity is too high and that it is appropriate for courts to react to that perception, tilting their decisions in favor of more safety."[15]

To put the point more colloquially, the courts that enforce this sort of deterrence rationale are saying that they've had enough of the level of accidents in particular kinds of activities, and they are not going to take it any more—that is, they will not be bound by efficiency constraints.

I suspect that the transportation of hazardous materials would be a kind of activity that would sometimes evoke this type of response, under various doctrinal umbrellas. I can only speculate as to some of the reasons, but my speculations center on the kind of horror evoked by the image of Bhopal, a sense that there is something particularly insidious about the long-term risks posed by exposure to some hazardous chemicals, and perhaps even an intuitive feeling that courts are a proper resort for injured persons when there are gaps in underfunded systems of regulation.

Justice and Fairness

The concepts of justice and fairness, which I collapse here under one heading, have been primary battlefields of arguments about the law for millennia. Here I shall focus on just a few ideas that have become associated with these broad concepts in the tort arena. Some ideas that seem particularly relevant to this inquiry include:

- The principle of individual responsibility. In a famous civil rights decision in the early 1960s, Justice Douglas captured this idea with a reference to "the background of tort liability that makes a man responsible for the natural consequences of his actions."[16] By extension, this principle applies to the artificial persons called corporations.

- The procedurally oriented notion that the law should provide relatively clear signals to entrepreneurs about the legal risks of the activities they undertake. This idea is in line with what I take to be one of the cardinal principles of

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14. Martin v. Ryder Truck Rental, Inc., 353 A.2d 581, 587 (Del. 1976).

15. M. Shapo, The Law and the Science of Causation: A Complex Synthetic, 1 Courts, Health Science & The Law 289, 291 (1991).

16. Monroe v. Pape, 365 U.S. 167, 187 (1961).

jurisprudence: that the law be known to the people who are subject to it. A colloquial way to put this principle is that it does not seem fair to hold someone to meet a standard that he or she didn't have reason to know existed.

- The related notion that within a given legal system, the law should be uniform. The policy tensions with respect to this idea are very high in a legal universe where there are daily struggles over whether federal legislation preempts state laws of various kinds. The desire for uniformity sometimes may collide head on with strongly held demands of citizens wearing their state insignia that courts should apply local law to occasions of injury.

  One of the most evocative battles on this subject, involving a dramatically important safety issue, occurred in a tort case whose subject provided the basis for a movie. The case involved the hazard of exposure to plutonium, which the Court of Appeals for the Tenth Circuit described as "one of the most carcinogenic and dangerous substances known."[17] The plaintiffs were the survivors of Karen Silkwood, an employee at a plant that made fuel pins for nuclear reactors, and the issue was whether punitive damages for plutonium contamination, otherwise awardable under state law, were preempted by the Atomic Energy Act. In his opinion for a majority of a divided Supreme Court, Justice White rejected the idea that the regulatory effects of a tort award swept it into the forbidden territory of atomic energy regulation that was fully occupied by the federal legislation.[18] As the history of hazardous materials transport proceeds through the nineties, we may expect replays of this issue.

- An idea that sometimes operates at odds with some of the concepts described above and sometimes dovetails with them is that of individualized justice. This is an idea that is closely related to the principle of individual responsibility, and it is one that sometimes conflicts with our desire for certainty and uniformity. It has been a center of contention, explicitly or implicitly, in many legal disputes. It fuels ongoing struggles between courts and legislatures and between states and the federal establishment. There is an age-old tension here that is familiar to all lawyers, and indeed all thoughtful citizens who observe the law in action. The more we focus on the justice of a particular case, the more pressure we put on our desire for general rules of broad application.

17. Silkwood v. Kerr-McGee Corp., 667 F.2d 908, 913 (10th Cir. 1981).

18. Silkwood v. Kerr-McGee Corp., 464 U.S. 238, 248-258 (1984).

BASIC LEGAL DOCTRINES

Having established this fabric of the rationales and goals of tort law, we may now focus on the theories of liability that are the working conceptual tools of courts and lawyers.

Theories of Liability

The fundamental doctrines on which courts rely in tort cases are the theories of liability. In the area we consider here, the menu is brief but rich.

Negligence. The workhorse of tort doctrine remains the concept of negligence, a term that describes conduct that falls below the level of a reasonable, prudent person in the conduct of the activity at hand. Given that abstract description, we proceed into a thicket of specific applications, making the preliminary observation that negligence law naturally concerns itself with levels of risk--risk both as to the frequency and severity of accidents.

How do courts go about determining whether conduct has met the appropriate standard of care? In practice, judges have drawn on a combination of ideas, explicitly and implicitly. They have looked to legislative and regulatory standards, where they exist. They have referred to the handbooks and manuals of professional and trade groups, even to those of particular corporate and governmental units, such as hospitals and police departments. And in situations in which they believe that the subject matter is within the ken of ordinary persons, they have left a good part of the task of setting standards to jurors.

In appellate decisions, at least, courts frequently have made reference to economic ideas. The all-time favorite benchmark has been the pronouncement by Judge Learned Hand that one may determine whether a party has exercised due care by figuring out whether the burden of accident preparation would have been less than the severity of the accident multiplied by its frequency.[19] On a parallel track, recent economic analysis has tended to emphasize the idea that if people are free, without "transaction costs," to strike their own bargains, it will make no difference to economic efficiency where one puts the liability.[20]

An important practical consequence of the economic approach to injury law is to emphasize the question of cost avoidance. Who is in the best position to avoid an accident at least cost, including the costs of searching out other parties and of bargaining and negotiation—that is, "transaction costs"? One of the most interesting presentations of this question occurs in situations involving hazardous substances of various kinds. One facet of this approach is prominent in Judge Posner's provocative

19. United States v. Carroll Towing Co., 159 F.2d 169, 173 (2d Cir. 1947).

20. The seed of this idea appears in a notable essay by Ronald Coase, The Problem of Social Cost, 3 J. L. & Econ. 1 (1960).

opinion in the *Indiana Harbor Belt* case, to which I shall refer later.[21]

Strict liability for abnormally dangerous activities. My mention of the *Indiana Harbor Belt* case leads me to another relevant theory of liability. In its most modern garb, that of the formulation of the Second Restatement of Torts, this is the theory of strict liability for "abnormally dangerous activities"[22]—a liability imposed even though the defendant has "exercised the utmost care to prevent the harm."[23] For present purposes, we may trace this theory to a nineteenth century English decision that imposed liability on a mill owner whose reservoir water gushed down into a mine that lay below the reservoir.[24] Many American courts have applied versions of this theory, although it has not been universally adopted in this country. Virginia Nolan and Edmund Ursin have capsulized some of the applications: "oil drilling, fumigation, crop dusting, commercial fuel hauling, agricultural field burning, and using explosives in isolated areas."[25] At least in the Second Restatement's version, this doctrine depends on an analysis of no fewer than a half dozen factors, including not only high degree of risk of an activity and the likelihood that it will cause great harm, but also the uncommonness of its usage and the "inappropriateness of the activity to the place where it is carried on." Most abstractly, the Restatement test refers to the "extent to which its [the activity's] value to the community is outweighed by its dangerous attributes."[26]

The list of applications that I have quoted above indicates that in some jurisdictions, this doctrine appears to be ready-made, if not tailor-made, for the transportation of hazardous materials. And, indeed, some courts have employed the doctrine in such cases. In one decision, the Washington Supreme Court applied strict liability to a case in which a fire occurred after a gasoline carrying tank trailer crashed through a highway fence. The court declared, "That gasoline cannot be practicably transported except upon the public highways does not decrease the abnormally high risks arising from its transportation." The Washington Court also said that the exercise of due care, which is all that the negligence standard requires, would not "assure protection to the public from the disastrous consequences of concealed or latent mechanical or metallurgical defects in the carrier's equipment, from the negligence of third parties, from latent defects in the highways and streets" and from all other hazards that the prudent person could not avoid.[27]

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21. See infra, text accompanying notes 36-42.

22. See Restatement (Second) of Torts §§ 519-520 (1977).

23. Id. § 519(1).

24. Rylands v. Fletcher, L.R. 3 H.L. 330 (1868).

25. Nolan and Ursin, The Revitalization of Hazardous Activity Strict Liability, 65 N.C. L. Rev. 257, 290 (1987).

26. Restatement (Second) of Torts § 520 (1977).

27. Siegler v. Kuhlman, 81 Wash.2d 448, 459-60, 502 P.2d 1181, 1187 (1972).

In a later, literally explosive case, a federal district court in California "follow[ed] the path of the Supreme Court of Washington" and said that strict liability could be imposed on the Southern Pacific Railway in a case in which eighteen boxcars, laden with bombs, exploded in the company's yard.[28] The company was hauling the bombs under contract to the Navy, but the court rejected the defendant's attempt to invoke a "public duty" exception to the strict liability doctrine. In upholding the claims of plaintiffs who sued for personal injuries and property damage against a motion to dimiss, the court commented that "[w]hether the carrier is free to reject or bound to take the explosive cargo, the plaintiffs are equally defenseless." Moreover, it said:

> Bound or not, Southern Pacific is in a position to pass along the loss to the public. Bound or not, the social and economic benefits which are ordinarily derived from imposing strict liability are achieved.[29]

I should add, for the sake of conceptual completeness, that this form of strict liability now has a very vigorous sibling in the law of products liability. With local variations, almost every American court, and now several state statutes, have applied a strict liability doctrine to consumer products. There is some potential practical, as well as theoretical, crossover between strict products liability and the strict liability for "abnormally dangerous activities" on which I have focused here. However, at the moment, I refer to strict products liability only to round out this part of the discusssion.

Nuisance. I also must add to this set of classifications the doctrines that move uneasily through the jungles of tort and environmental law under the collective title of "nuisance." Private nuisances have a conceptual fit with various basic tort doctrines, embodying basic tort notions of intentional conduct, negligence and strict liability.[30] The primary concept underlying the idea of nuisance is that of interference with someone's interest in the use and enjoyment of their land.[31] The doctrine of public nuisance requires courts to analyze a complex group of "circumstances" in deciding that someone has perpetrated "an unreasonable interference with a right common to the general public."[32] In this country, the nuisance doctrines have tended to be reserved for pollutants, stenches and other noxious emanations from standing sources that endure over a period of time.

If we visualize the typical case of injury potentially attributable to hazardous materials transportation as a spill, the operative doctrines are likely to be those of

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28. Chavez v. Southern Pac. Transp. Co., 413 F. Supp. 1203 (E.D. Calif. 1976).

29. Id. at 1214.

30. See generally Restatement (Second) of Torts § 822 (1979).

31. See id.

32. Id. § 821B.

strict liability for abnormally dangerous activities and negligence. Yet if we broaden our thinking to include the process of frequent transportation of such goods through communities, a case for nuisance doctrine emerges that is more than theoretical.

A Problem Common to Various Doctrines. The doctrines I have sketched exhibit significant verbal and conceptual differences. Yet they also present substantial areas of overlap in the sorts of challenges that they present to courts. One of the most important challenges lies in the fact that in one way or another, each doctrine forces courts to deal with the problem of social utility.

Theoretically, one might finesse many potential difficulties by having courts rely entirely on market solutions to problems. Judges might simply ask what educated, informed bargaining parties would precast as their solution to situations in which accidents might occur. As I have intimated, however, courts have found this kind of solution much easier to express than to effectuate. One reason relevant to transportation of hazardous materials is that it ordinarily would be impracticably expensive for people who might be injured by explosions or spills to bargain with transporters and carriers about risk. Economists would call this a problem of high transaction costs. Among other obstacles to this form of theorizing are difficulties of valuation, including valuation of accident costs, avoidance costs and transaction costs.

Most important, tort law is, in practice, a multiple purpose vehicle that carries many social interests. Thus, the problem of measuring social utilities becomes in significant measure a problem of defining social values. We see this, not infrequently, in such areas as the law of products liability. Confronted with cases involving the materiel of medicine—blood and drugs, for example—the courts announce a premium, socially derived, for the encouragement of research, development and manufacture.[33] Moreover, the catalog of factors associated with strict liability for abnormally dangerous products is heavy with implications that judges are determiners of social values. How else would courts decide about the "inappropriateness" of an activity or its "value . . . to the community"?[34]

Causation, Duty and Damages

The theories of liability are the conceptual pivot of the basic legal doctrines that

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33. See, e.g., Doe v. Travenol Laboratories, 698 F. Supp. 780, 784 (D. Minn. 1988), in which the court dismissed an action by a plaintiff who contracted AIDS-Related Complex from an antihemophilic factor. Referring to the fact that the market for such products was relatively small, the court mentioned its concern that the availability of such products "would be threatened if the cost of the inherent risk of HIV infection were imposed on the manufacturer."

34. See the language of Restatement (Second) of Torts § 520, cited supra, text accompanying note 26.

bear on the imposition of damages for injuries caused by hazardous materials transportation, as they are for any injuries that come into the tort system. Yet there are other elements that also are basic to any torts case, including causation, duty and damages.

Causation. A fundamental requisite of most torts cases is that the plaintiff show that his or her injury was caused—caused in fact—by the defendant's conduct or product. In any case involving chemical spills, this will be an issue. We have learned, in this chemical age, that the legal answer to the question will depend basically on probabilities. Since we cannot see the molecules of a particular chemical at work on the tissues of someone's organs, we must draw inferences from a variety of sources about whether that substance caused a particular disease. Various actors in the scientific community offer diverse contributions to these determinations: clinical physicians, epidemiologists, toxicologists, clinical ecologists. Litigation frequently turns into a battle of experts over the inferences that properly may be drawn from particular chains of events. Last year I served as Reporter for a full symposium on this subject, scholarly contributions to which now occupy several hundred pages in a journal published earlier this year.[35] In the context of my present assignment, I can only refer to that volume as a beginning point for analysis of the knotty question of "causation in fact."

Duty. Another basic requirement of tort law is that the plaintiff demonstrate that the defendant owed a duty to him or her. If a quarter century of torts teaching gives me some clinical qualifications as to the degree of difficulty associated with a legal idea, I would have to say that this is one of the most conceptually slippery parts of this area of the law. One reason it is so difficult is that the question of "duty" often is conflated, erroneously, with notions of "proximate cause."

That concept, indeed, presents an especially baffling mask in the tort drama. Courts sometimes use the term "proximate cause" when they really mean "cause in fact." But perhaps even greater confusion arises when they use the language of "proximate cause" to try to solve such problems as whether to limit liability geographically, or temporally, or with reference to the kinds of losses that have been suffered. Consider, for instance, a case of a chemical spill. The fumes injure Ms. A; some sticky by-products foul Mr. B's front doorstep. The need to clean the spill from a road leading to a major bridge forces traffic out of its way by many miles, with attendant costs in gasoline for Carrier C. And Ms. D cannot get to work at her office, which has been declared off limits because of contamination, and thus loses her salary. Some courts might denominate as an issue of "proximate cause" the question of whether the firm responsible for the spill must compensate for each of these undoubted injuries.

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35. Papers from this meeting are collected in Symposium, Legal and Scientific Perspectives on Causation, 1 Courts, Health Science & The Law No. 3 (1991). The writer's overview is Shapo, The Law and the Science of Causation: A Complex Synthetic, id. at 289.

But if we assume that there was competent evidence and the spill was factually a sine qua non cause for all these harms, putting the adjective "proximate" into the legal formula does not seem to help us further to define cause. The question of whether we differentiate Carrier C and Ms. D from Ms. A and Mr. B is really—as Green brilliantly showed—one of policy for the court. It is a question that depends on how we visualize the legal relationship between the defendant and each plaintiff. As a question of duty, it requires the court to delve into precedent, reason, notions of social utility, and not least, common sense.[36] That may seem imprecise to you, but I can give you as much assurance as is possible for a reader of torts cases that you will get no more certainty from the concept of "proximate cause."

Damages. The payoff in any torts case, literally, turns on the question of damages. The traditional items of tort damages are well known, principally including lost wages, medical bills, and pain and suffering. Within these categories, there is currently a lot of aggressive bumping as plaintiffs try to broaden the field of battle and defendants try to keep it limited. One major theoretical battleground is over the amount--for some critics, even the existence—of such noneconomic damages as pain and suffering. A principal issue in cases involving various kinds of toxic products focuses on the costs of medical monitoring for people who have been exposed to a product but do not manifest signs of clinical illness. Moreover, arguments currently rage over the question of whether people who can demonstrate exposure and a high probability of illness, but not illness itself, should be able to recover for their fear of disease in the future.

Apportionment Issues. A final issue of great practical significance concerns the apportionment of liability among the various parties to the carriage of hazardous materials: manufacturers, shippers and transporters. This issue partakes of other categories of basic tort elements, especially cause in fact and damages. Broadly speaking, a principal judicial goal in apportionment of liability is to assess to each

36. Cf. Brown v. Channel Fueling Service, Inc., 574 F.Supp. 666 (E.D. La. 1983), a case involving an oil spill that resulted from a collision between vessels on the Mississippi River. When the collision occurred, the plaintiff was working on a barge that was about six miles downstream. The oil from the spill reached the barge about six hours later, washing up on the deck. Two days later, as the plaintiff tried to clean up the deck, on which the oil "had congealed into a soft tar-like substance," he slipped and fell. Denying liability against the owner of one of the "colliding vessels, the federal district judge drew on a "'legal cause' analysis." Saying that he thought "that a limit must be placed as to how far a defendant's responsibility should extend," he declared "that at some point common sense must take over." In this case, he concluded, the injury was "too remote from the collision, both in time and space, for plaintiff to recover." He further opined that "it simply was not foreseeable that oil which spilled into the Mississippi as a result of a collision would splash aboard a barge miles away and cause someone to slip some two days after the accident." Id. at 668.

party the true social cost of its contributions to an injury. Practically, the subject becomes mired not only in the realities of pre-accident contracts between parties, but also in the legal technicalities of the doctrines of indemnity, contribution and comparative contribution.

IMPLICATIONS OF LEGAL DOCTRINES AND POLICIES

I now want to distill some of the practical messages that emerge from this background of doctrine and policy. I should emphasize that even though doctrines themselves sometimes seem to take on lives of their own, in the end legal theories are functions of the realities from which they have grown and the policies that they serve.

The $64 million question is: How are courts likely to respond to claims for injuries caused by the transportation of hazardous materials? It happens that—in the words of a famous musical show—we have an answer that arose from an episode "right here in River City." Or, I should say, two answers.

The two answers are the conflicting decisions of the federal district court in Chicago and the Court of Appeals for the Seventh Circuit in the case of *Indiana Harbor Belt R.R. v. American Cyanamid Co.*[37] The case involved the shipment of 20,000 gallons of liquid acrylonitrile, a chemical used "as the raw material for the acrylic fibers used in many types of clothing"[38] and also employed in the manufacture of a variety of other products, including "plastics, dyes, pharmaceutical chemicals, and other intermediate and final goods."[39]

The spill occurred just south of Chicago in the Blue Island yard of the Indiana Harbor Belt Railroad (IHB), which lies in the Village of Riverdale. Cyanamid had loaded the chemical in Louisiana in a car leased from North American Car Corporation for shipment to New Jersey. The Missouri Pacific Railroad picked up this car and took it to Chicago, leaving it on the IHB tracks in the Blue Island yard for another pickup by Conrail, which was to carry the car to New Jersey.

Although the IHB did not handle the cars, it charged "a small fee for the use of its tracks," and its employees made "[a] routine walking inspection of the train" that "revealed no problems." Some hours later, however, IHB workers "noticed a substantial flow of liquid coming out of the bottom outlet" of the tank car. They saw that the reducer pipe coming out of that outlet had broken off, but were unable immediately to stop the flow. It was only after further measures, following movement of the car to a siding at the order of the Riverdale Fire Department, that the leak was stopped. In their efforts to deal with the leak, IHB employees found various loose and missing pieces inside the box that covered the valve control, which had been sealed by Cyanamid when it loaded the car. Further inspection showed

37. 662 F. Supp. 635 (N.D. Ill. 1987), rev'd, 916 F.2d 1174 (7th Cir. 1990).

38. See 662 F. Supp. at 637

39. 916 F.2d at 1175.

other loose and missing parts.[40] The suit by the railroad sought damages against Cyanamid for the nearly one million dollars it cost IHB to clean up the spill.

Judge Moran of the district court found this a case for strict liability. Analyzing the case in light of the factors developed by the Second Restatement of Torts to judge allegations of "abnormally dangerous activities," he adduced the highly combustible nature of the product as well as its toxicity.[41] He thought that "perhaps the single most important factor" in the equation was "the 'inappropriateness' of bringing the danger to the particular place where the damage occurred." Viewing the facts from that perspective, he noted that the "Blue Island yard adjoined a residential area," that "[s]ome 3,000 people had to leave their homes for a time after the spill," and that "[c]leanup costs were high because the spill contaminated the water supply for those and other nearby residents." These facts, he thought, made "[s]ending thousands of gallons of this toxic chemical through the Blue Island yard . . . seem[ ] singularly 'inappropriate' in the Restatement sense of the word, given the character of the area surrounding the yard."[42]

Although Judge Moran conceded the industrial and commercial value of the chemical, and noted his awareness of the "important role in Louisiana's economy" played by "chemical plants such as Cyanamid's," he insisted that "what one considers is the value of the activity not nationwide, but to the specific community or area damaged by it."[43]

The Seventh Circuit disagreed, refusing to apply strict liability to Cyanamid. Judge Posner's opinion for that court posited that there was no suggestion "that the leak in this case was caused by the inherent properties of acrylonitrile." Rather, he premised—indeed, gave as a factual conclusion—that "[i]t was caused by carelessness"—that of the lessor of the car, or Cyanamid, or the Missouri Pacific, or "the switching line itself . . . or some combination of these possible failures of care."[44]

From this foundation, Judge Posner moved to the conclusion from the record that "if a tank car is carefully maintained the danger of a spill of acrylonitrile is negligible." This, he indicated, seemed to point to the conclusion that there was "no compelling reason to move to a regime of strict liability, especially one that might embrace all other hazardous materials shipped by rail as well."[45]

Judge Posner launched a side volley at legal allies of Cyanamid for their predictions of " 'devastating' effects on the chemical industry" if strict liability were applied. He observed that "if the vast majority of chemical spills by railroads are preventable by due care, the imposition of strict liability should cause only a slight,

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40. This recitation draws principally on the district court's summary of the facts, 662 F. Supp. at 637-38.

41. See 662 F. Supp. at 638.

42. See id. at 641-642

43. See id. at 643-44

44. 916 F.2d at 1179.

45. Id.

not . . . substantial rise in liability insurance rates, because the incremental liability should be slight."[46] At the same time, however, he stressed the economic problems that would result from the application of strict liability in this situation. Since Chicago is "one of the nation's largest railroad hubs," he observed, it was "unlikely" that hazardous chemicals—many ranked more hazardous than acrylonitrile—could be "rerouted around all the metropolitan areas in the country, except at prohibitive cost."[47] Moreover, Judge Posner pointed out, rerouting would be "no panacea," for "[o]ften it will increase the length of the journey, or compel the use of poorer track, or both." This would actually increase the probability of accidents, "even if the consequences of an accident if one occurs are reduced." Thus, "the expected accident cost, being the product of the probability of an accident and the harm, if the accident occurs, may rise."[48] He reiterated that one could visualize that the exercise of more "care on the part of those who handled the tank car" might have prevented the accident, but thought it "difficult to see how it might have been prevented at reasonable cost by a change in the activity of transporting the chemical."[49]

Raising but dismissing the possibility that one might alter the legal conclusion by characterizing Cyanamid "as a special type of shipper (call it a 'shipper-transporter')," Judge Posner moved to a stark definition of the situation in economic terms. The problem, as he saw it, was that the application of strict liability might "create—perhaps quixotically—incentives to relocate the activity to nonpopulated areas, or to reduce the scale of the activity, or to switch to transporting acrylonitrile by road rather than by rail." In that regard, he emphasized, "[i]t is no more realistic to propose to reroute the shipment of all hazardous materials around Chicago than it is to propose the relocation of homes adjacent to the Blue Island switching yard to more distant suburbs." Indeed, "[i]t may be less realistic."

And then came the grenade from the trenches of economic analysis of law: "Brutal though it may seem to say it, the inappropriate use to which land is being put in the Blue Island yard and neighborhood may be, not the transportation of hazardous chemicals, but residential living."[50] So Judge Posner, never hesitant to provoke and always fearless in the pursuit of his analytical framework wherever it leads, now says in a judicial opinion something with which I have been creating outrage in first year students for many semesters: From an economic standpoint, perhaps the best use of the mythical Happy Valley of classroom hypothethicals is not for homes, but as a sink for pollution.

What can we divine from this clash of opinions? Those who seek predictability

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46. Id.

47. Id. at 1180. In this connection, Judge Posner had noted that acrylonitrile was ranked as only the fifty-third most hazardous "of the 125 hazardous materials shipped in volume on the nation's railroads." Id. at 1178.

48. Id. at 1180.

49. Id. at 1181.

50. Id. at 1181.

from the law, I am afraid, must resign themselves to a significant level of uncertainty. I suspect that the conflicting opinions in the *Indiana Harbor Belt* case will provide some of the raw material for more legal conflict over the next several years.

We can certainly identify some of the principal factors that will be at work as attorneys present their cases to courts. Obviously, those factors include the high degree of danger and the resulting potential for serious and large-scale injuries to communities bordering routes of shipment. There is the fact that the goods of which we speak are literally part of the warp and woof of our society—the *Indiana Harbor Belt* case is nicely symbolic, because it involves a chemical directly used to make the clothes on our backs. There also is an element of the problem that is hard to put on a graph, but one that I suspect infects judicial minds as well as the emotions of ordinary citizens. That is fear—fear of the known (we have all read of Bhopal) as well as fear of the unknown.

There also is a factor that ties in with my description of the kind of deterrence philosophy that does not rely principally on economic theory: the idea that there are just too many accidents, or that a class of injuries is too severe, to tolerate a particular kind of conduct without at least requiring compensation for it. In this regard, we must confront the possibility that when confronted with incidents like chemical spills, many judges are likely to have a self-conscious vision of themselves as moral agents of the community, with a mandate to make judgements that go beyond considerations of economic efficiency. We may refer again to the Delaware Supreme Court's decision applying strict liability against the renter of a motor vehicle, in which the court spoke of the economic environment as "requir[ing] maximum protection for the victims of defective rentals."[51] Although courts using such language may not be entirely dismissive of the costs of liability judgements, such terminology implies that they do not consider technical efficiency constraints to impose a fixed limitation on liability. Bolstering the interpretation that moral concerns underlie such judicial pronouncements is the same court's statement that one of the policy reasons for strict liability is that it "will result in general risk-reduction by arousing in the lessor an additional impetus to furnish safer vehicles."[52] The language of "general risk reduction" is not the language of nice calculations of economic efficiency.

It is difficult to predict how this legal drama will play itself out in the nineties, and in the next century. I will offer these semi-educated guesses: At the bottom of cases involving serious episodes of injury from hazardous materials transportation—as indeed Judge Posner suggests—there is likely to be negligence. In some cases, it may be difficult to discover who was not careful, but in such instances, even negligence doctrine may provide ways to infer a lack of due care, for example, through the time-honored doctrine of *res ipsa loquitur*. That theory of circumstantial evidence permits fact-finders to infer negligence in situations in which reasonable

51. Martin v. Ryder Truck Rentals, 353 A.2d 581, 587 (Del. 1976), discussed text accompanying note 14 supra.

52. Id.

persons may conclude that injury ordinarily would not have occurred in the absence of negligence. This indicates that transporters will reasonably take the same message from any conceivable profile of law that will confront them that Eads and Reuter drew from the responses of corporate executives to products liability law: "Be careful, or you will be sued."[53]

At its broadest, this advice applies to all facets of the process of transportation. Since negligence reaches to planning as well as execution, I expect it would apply in theory to the selection of routing systems, although it is difficult to visualize any court calling a transporter negligent for not spending several billion dollars to create a new, hermetically sealed corridor for its cargo. Besides viewing themselves as moral standard bearers, judges are pretty sensible people—the roles are frequently consistent with each other—and they reflect their reverence for practical economics every time they cite Learned Hand's negligence formula.

Perhaps the greatest area of uncertainty is as much factual as legal. That is, how many hazardous materials accidents really occur when there is no negligence? It may be that in some percentage of cases, courts will follow the district court in the Indiana Harbor Belt case and require compensation under a strict liability theory. But if Judge Posner is correct in hypothesizing that the imposition of strict liability would not significantly drive up insurance rates,[54] then the worst effect on transporters of any conceivable liability regime would be a relatively marginal forced loss-spreading rather than a dramatic conduct-regulating impact.

SOME CONCLUDING OBSERVATIONS

I want to conclude with some general, somewhat speculative thoughts about the role of liability rules in our society. Some of my thoughts about the intertwining of legal rules and public policy arise from an informal suggestion by my colleague Jay Hillman that it would be interesting to consider how we would set up our liability regime if a governmental institution were in charge of all transportation of hazardous materials. Professor Hillman was thinking, I believe, about the notion that there might be some activities that are so important that government should take them on even if the private sector would not, at the same time limiting its liability in a way that private entrepreneurs could not. This suggestion was appealing to me for a collateral reason, because it helps to focus analysis on the social costs and benefits of transportation of hazardous materials, an activity that principally, although not exclusively, takes place in the private sector. In that more typical setting, we rely on the market to make our cost-benefit calculations in the context of applicable law. If the government were the prime actor, it would combine the roles of promulgator of liability rules and regulator, as well as the role of social choice maker presently played by the market, in one briefcase.

53. See text accompanying note 7 supra.

54. See text accompanying note 46 supra.

What would be the applicable rules of law in such a setting? At least at a general level, we do not have to guess; we know. The Federal Tort Claims Act, and its interpretations by the Supreme Court, tell us. The legislation itself provides jurisdiction in federal courts for suits for injury "caused by the negligent or wrongful act or omission of any employee of the government while acting within the scope of his office or employment, under circumstances where the United States, if a private person, would be liable."[55] There are substantial limits on this liability. The Supreme Court has held, and reconfirmed, that it does not include "absolute liability" for " 'extra-hazardous' activity."[56]

Moreover, Congress itself has emphasized that the government's liability does not extend to "the exercise or performance or the failure to exercise or perform a discretionary function or duty on the part of a federal agency or an employee of the Government."[57] This "discretionary function" exception has been used to immunize the government in a variety of circumstances, of which the leading case still is one that involved the transportation of explosive material. This case involved claims of enormous damage from an explosion of fertilizer on board a ship, an event that "leveled" "[t]he entire dock area of a thriving port"—that of Texas City—and caused more than 560 deaths and 3,000 injuries.[58] The Supreme Court's decision in the Texas City Disaster case dealt with claims that there were several acts of negligence in the manufacture of the fertilizer, which was destined for European relief in the desperate period immediately following World War II. In particular, the plaintiffs cited high bagging temperatures, the combustibility of the bagging used for the fertilizer and the allegedly ineffective warnings on the bags, as well as the explosive character of the coating used on the product. The court concluded that "[t]he decisions held culpable were all responsibly made at a planning rather than operational level and involved considerations more or less important to the practicability of the Government's fertilizer program."[59]

In addition to this legislative and judicial history centering on the Federal Tort Claims Act, we also know that when Congress sets up a regulatory system, it may seek to prevent state instrumentalities, including courts, from making decisions that intrude on the policy decisions inherent in that system. The Silkwood case, however, indicates that Congress must be very clear about its intentions if it wishes to take the turf of the common law from its creators, the state courts.

We also possess one other set of legal facts. We know that the state courts have created a broader liability regime than the one available under the Federal Tort

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55. 28 U.S.C. § 1346(b) (1988).

56. Dalehite v. U.S., 346 U.S. 15, 44-45 (1953); Laird v. Nelms, 406 U.S. 797, 802-03 (1972) (using characterization of "strict liability for ultra-hazardous activity").

57. 28 U.S.C. § 2680 (1988).

58. See Dalehite, supra note 56, 346 U.S. at 48 (Jackson, J. dissenting).

59. See the majority opinion by Reed, J., id. at 42.

Claims Act. Generally, that regime includes negligence in planning as well as execution, although I should note that findings of "no negligence," in cases where private persons have made reasonable judgements between or among hard choices, may sometimes be equivalent to a holding that government officials were exercising a "discretionary function." In some jurisdictions, the existing body of tort law also includes strict liability, and in practically all states, negligence law includes rules that allow claimants to present circumstantial proof that defendants fell below the standard of due care.

Thus, we grant the government somewhat more leeway than we would grant a private defendant who transports hazardous goods. In this regard, shippers and carriers might usefully focus on their roles as ordinary consumers rather than as business persons taking part in the activity of commercial transportation. If we look at the subject from that point of view, we see interesting parallels between our relationship with the government, of which we are organically a part, and our relationship as consumers and homeowners with those who engage in this definably risky activity. With the latter group of actors, we also share an organic relationship, since they literally fuel and clothe us, as well as provide us with other goods.

What joins us as citizens and consumers under the law is the way our general perceptions of and attitudes toward risk and benefit become fused in the rules of common law and legislation.

We could, of course, allow the federal government to set all the rules, including liability rules, for the carriage of hazardous materials. If we did that, we would substitute a relatively politicized process for a system, principally rooted in tort jurisprudence, that works tolerably well for resolving disputes about injury in a relatively decentralized fashion. But before we settled on that solution, we would want to ponder the development of a half century of law and politics in the field of nuclear energy. Among the fragments of history we would encounter would be these: The Atomic Energy Act presumably struck a balance between development and safety in the peacetime uses of the atom. Many years after the passage of amendments to the legislation that sought to bar state regulation of nuclear safety, a federal jury in Oklahoma awarded the survivors of Karen Silkwood, a laboratory analyst in a plant that made fuel pins for reactors, a great deal of money for her exposure to plutonium, including $10 million in punitive damages.[60] And today, rightly or wrongly, and permanently or temporarily, the politics of nuclear energy have brought about a situation in which no new reactors are being built for power generation in the United States.

Truly, at some level, all law is politics. This essay has sought to be descriptive, and occasionally predictive, rather than judgemental. But in conclusion, I present one modest brief for our existing liability law, including its doctrinal components of negligence, strict liability and nuisance. That is the argument that this branch of the law, for all its faults, is a useful bridge between the impossible world of a completely

60. The case eventually was settled for much less than the jury award. See Moss, Silkwood Case Settled, A.B.A.J., Oct. 1, 1986, at 32 (reporting Kerr McGee's agreement to pay $1.38 million to Silkwood's estate).

laissez-faire economy and the highly undesirable world of an all-encompassing, preemptive regime of regulation.

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THE LAW AND ECONOMICS OF HAZARDOUS MATERIALS TRANSPORTATION: REGULATING HARM BY ADMINISTRATIVE AGENCY AND TORT LIABILITY

Thomas S. Ulen and Charles Kolstad[1]

ABSTRACT

This paper concerns the appropriate method of regulating the transportation of hazardous materials. These materials, when in transit, present the possibility of harm to innocent parties and thus raise the public policy issue of how best to achieve the socially optimal amount of precaution. Current policy relies principally on ex ante administrative agency regulation of shippers through the Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA). There is a complementary method of regulating these harms—exposing the potential wrongdoer to ex post tort liability. We argue here for two changes in current policy: (1) relatively greater reliance than is currently the case on ex post tort liability and less reliance on ex ante administrative agency regulation, and (2) a method for deciding whether strict liability or negligence liability is the more appropriate liability standard to use to achieve the socially optimal amount of precaution from harms arising from the transportation of hazardous materials.

INTRODUCTION

The production, generation, transportation, and usage of hazardous materials and wastes with which they may be associated have presented policy makers with some of the thorniest issues of recent decades. There is an interest in properly balancing the social benefits of the production of the outputs against the social costs of harms arising from exposure to those materials and their wastes.

From an economic standpoint, the harms arising from the generation, transportation, and disposal of hazardous and toxic materials are "external costs." These are costs generated in the course of utility- or profit-maximizing activity that are borne involuntarily by noncontractual parties to the activity. Thus, for example, someone who suffers from a mutagenic harm because of the ingestion of a hazardous material

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1. We would like to thank the participants in the Hazmat Transport '91 Conference for many helpful comments on the version of this paper that was presented at the conference.

or someone whose property is seriously damaged because of a chemical leak is bearing the external costs of someone else's incautious actions. In the absence of a public policy that induces the generator of the external cost to take account of these potential harms to others, the externality generator will tend to engage in too much of the harmful activity. He does so because he is not forced to bear the full social costs of his potentially harmful activity. The goal for a sound public policy is to induce him to take account of both his own direct costs and the indirect costs his activities may impose on others. If the policy instruments are articulated precisely enough, then the externality-generator will be induced to take the socially-optimal amount of precaution. The result should be that, put somewhat formally, the social costs of accidents (the sum of precaution, accident, and administration costs) will be minimized.

Public policies designed to achieve these goals are of two general forms. The first—called ex ante regulation—is characterized by explicit regulations designed to control the externality-generating activity by imposing time, manner, and place restrictions on the potential wrongdoer. Typically, the regulations are established by an administrative agency acting under statutory authority and are administered and enforced by that agency through monetary and other sanctions. Examples are the series of regulations of the United States Environmental Protection Agency (EPA) and its state-level equivalents that are designed to minimize harm to the environment. The second—called ex post regulation or, alternatively, regulation through the tort liability system—is a system of private enforcement: victims of tortious wrongs may seek compensatory damages for their losses from those whom the court may deem liable for the wrongs. The tort liability system intervenes only after a harm has been inflicted. Theretofore, the potential victim and the potential wrongdoer order their own affairs. Presumably, they are induced to take precaution against an external harm by the fear of having to bear financial liability for the harms imposed on others.[2]

These general remarks on the goals and instruments of public policy toward externality generators apply directly to the potential harms that arise in the generation, transportation, use and disposal of hazardous and toxic materials. There are a host of federal and state agency regulations and tort liability holdings applicable to those materials. In this paper we want to focus on the mix of public policies governing potential harms that arise in the transportation of hazardous materials. Those harms are principally controlled by means of ex ante regulations, such as those embodied in the HMTUSA. The role that is currently played by exposure to ex post regulation through the tort liability system is much weaker.

We shall argue that this division of labor between ex ante and ex post regulation in dealing with harms from the transportation of hazardous materials is misplaced. Greater reliance should be placed on exposing transporters of these materials to strict liability and less on trying to govern the time, manner, and location of transportation.

We shall proceed by first giving some very brief background on the extent of the harms to which innocent parties are exposed by the transportation of hazardous

2. Other factors, such as a concern for oneself and for one's insurance rates, induce the potential injurer to take appropriate account of harms that his carelessness may cause himself.

materials and on the regulations that govern that transportation. Then we shall describe briefly the status of tort liability for harms arising in the course of transporting hazardous materials. Next we shall summarize a theory of the appropriate tort liability standard to use in harms involving hazardous materials and of the appropriate division of labor between administrative agency regulation and exposure to tort liability. What we shall find is, first, that the emerging tort liability standard in this area may be incorrect and, second, that social welfare would probably be improved by relying less on the ex ante regulation imposed in statutes like HMTUSA and more on holding wrongdoers strictly liable for any harms that arise in the transportation of hazardous materials.

BACKGROUND

The transportation of hazardous and toxic materials has become a large business in the United States. The United States Department of Transportation (DOT) estimates that 4 billion tons of regulated hazardous materials move across state lines each year. There are, the DOT further estimates, an average of 500,000 movements of those materials every day. This transportation is part of a large and rapidly-growing industry devoted to the disposal of hazardous and toxic wastes. EPA estimated that the revenues of the commercial hazardous-waste disposal industry in 1990 were between \$3.5 billion and \$4.5 billion and that in the recent past those revenues have been growing at a rate of 20% per year.

The immense volume of hazardous material has generated a correspondingly immense amount of regulation, both at the state and federal levels. For instance, the federal Resource Conservation and Recovery Act (RCRA, originally passed in 1976 and amended in 1984) imposes recording, siting, training, and other constraints on the generation and disposal of hazardous materials and their wastes. The federal Comprehensive Environmental Resource, Compensation, and Liability Act (CERCLA, 1979)—known as the "Superfund" Act—establishes fees on generators of hazardous wastes that are to be used to clean up abandoned disposal sites and establishes the terms of liability actions for the recovery of compensatory and punitive damages for harms imposed by the disposal of hazardous wastes. In 1977 the Civil Aeronautics Board (CAB) instituted an investigation of rules regarding the acceptance of hazardous materials as cargo,[3] and other federal regulatory agencies, such as the Department of

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3. The CAB terminated the investigation in 1980 because its breadth had grown larger than the board felt competent to handle. See 87 *C.A.B.* 1155 (1980). However, during the 1980's and after the demise of the CAB, the Federal Aviation Administration interpreted its power to grant licenses for the public convenience and necessity to include a requirement that someone at the applicant-airline be responsible for and trained in the handling of hazardous materials. See §204.4 of the USDOT's regulations interpreting §401(d)(1) of the Federal Aviation Act of 1958, as amended, and *Application of Arctic Circle Air Service, Inc.*, 1990 *DOT Av. LEXIS* 958 (Nov. 28, 1990).

Transportation and the EPA, regulate parts of the hazardous and toxic materials industries.

At the state level, regulations going beyond RCRA and CERCLA have become common. Some states, such as Illinois and Massachusetts, have forbidden the landfilling of hazardous wastes.[4] Recently, Texas, the largest producer of toxic chemicals in the country, announced a halt in the issuance of permits for commercial hazardous waste sites till at least September, 1991.[5] South Carolina and North Carolina are arguing about interstate shipments of hazardous and toxic materials. Alabama, the home of the largest commercial hazardous-waste landfill disposal site in the country, at Emelle, has sought, thus far unsuccessfully, to restrict the further importation of hazardous and toxic wastes to that facility.

For many years the focus of state and federal regulation of hazardous and toxic materials has been on the generation and, especially, the disposal of those materials. Although Congress passed the Hazardous Materials Transportation Act in 1975, transportation has been relatively unregulated in comparison with the other aspects of the hazardous waste industry.[6] The increasing reluctance of localities and states to serve as disposal sites, as evidenced by the actions reported above, has meant a rapid increase in the volume of hazardous materials transported across state lines by rail and by truck. This increase, in turn, caused Congress to take a fresh look at the regulation of the surface transportation of these materials.

The result of this fresh look was the passage in late 1990 of HMTUSA. The act is long and complicated, but its central premises for the student of the regulation of externalities are straightforward. First, the act seeks to bring uniformity to the

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4. Illinois made landfilling illegal as of January 1, 1985. For an analysis of the adverse consequences of that act, see J. Lon Carlson, Gary V. Johnson, and Thomas S. Ulen, "An Economic Analysis of Illinois' New Hazardous Waste Disposal Law," 24 *Nat. Res. J.* 865 (1984).

5. See *New York Times*, February 19, 1991, A8, col. 1. Texas has 11,000 businesses that generate regulated hazardous wastes. Those businesses generate 70 million tons of waste annually. As is the case in the rest of the country, the majority of that waste is disposed of by the generators in their own incinerators or dumps. However, there are more than 60 independent commercial hazardous-waste disposers in Texas. Nine new facilities opened in 1990, and the action suspending new permits is said to have stalled 35 additional projects.

6. The word "relatively" is meant to be stressed here. There *has* been study and regulation of the surface transportation matter. See, e.g., Glickman, "Analysis of a National Policy for Routing Hazardous Materials on Railroads," (United States Department of Transportation, Research and Special Programs Administration, Transportation Systems Center, May, 1980); Glickman and Harvey, *Statistical Trends in Railroad Hazardous Material Safety, 1978 to 1984* (Draft Final Report to the Environmental & Hazardous Materials Studies Division of the Association of American Railroads, April, 1986); and Office of Technology Assessment, *Transportation of Hazardous Materials* (1986).

regulation of the transportation of hazardous wastes. Many shippers felt that the states had developed a welter of regulations that were inconsistent with one another and that imposed significant and socially wasteful costs on the transportation industry. Under HMTUSA states retain some flexibility in their regulation but must—as with environmental regulations—adhere to federal standards for classification, packaging, handling, and marking of shipments and must follow federal guidelines in designing highway routes for the transportation of hazardous materials. Second, the act requires all shippers of hazardous materials to be licensed and to pay fees between $250 and $5,000 for those licenses.[7] The revenues from these licensing fees would be used to train state emergency-response teams to deal with spills of hazardous materials on highways and railroads. Additional funds were also appropriated over the next six years to fund these state-based teams. Third, civil and criminal penalties for violations of the provisions of the act were increased substantially over the levels of the 1975 Act. Fourth, the act provides for an increased number of federal inspectors to enforce the act's provisions over all forms of surface transportation. Finally, the act instructs the U.S. DOT to improve the current system of posting notices and warnings on vehicles that are shipping hazardous materials and urges the department to study the advisability of a central registration and reporting system.[8]

A THEORY OF EX ANTE AND EX POST METHODS OF REGULATING HAZARDOUS MATERIALS TRANSPORTATION[9]

All of these federal and state regulations reflect a genuine and legitimate concern with the potential adverse consequences of hazardous and toxic materials. However,

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7. Since this paper was presented, DOT set the annual fee at $300 for companies that " 'transport or cause to be transported' specified quantities of radioactives; more than 25 kilograms of class A or B explosives; more than one liter per package of substances that are extremely toxic if inhaled; or placarded shipments of 5,000 pounds or more of packaged hazmats from one shipper" (*Transport Topics*, July 13, 1992, p.1).

8. It is also worth noting that just as the interstate transportation of hazardous materials increased in the 1980's with the increasing reluctance of states and localities to serve as disposal sites, so has the international shipment of those materials. This trend toward increasing international shipment is fueled by both the secular increase in international trade and the increased use of incineration at sea as a method of disposing of hazardous and toxic materials. On the legal issues present by these international shipments, see E. Orlando, "Recent Developments Concerning the Legal Regime and Insurance Problems related to the Transportation of Hazardous Materials by Sea," in H. Kunreuther, ed., *Insuring and Managing Hazardous Risks* (1990).

9. This section is based on Charles D. Kolstad, Thomas S. Ulen, and Gary V. Johnson, "*Ex Post* Liability for Harms vs. *Ex Ante* Safety Regulation: Substitutes or Complements?" 80 *Am. Econ. Rev.* 888 (1990).

that is not to say that the regulations have been designed to optimally balance the social costs and benefits of the generation, transportation, and disposal of hazardous materials. To assess these regulations, we must have a standard. In this section we turn to the issue of specifying the optimal means of regulating the transportation of hazardous materials.

Introduction

One of the main issues that dominates the economic literature on optimal regulation is the choice of the most efficient policy for correcting an externality. From its beginnings the literature has focused on alternative forms of what we have called ex ante policies (e.g., safety standards, Pigouvian taxes, and transferable discharge permits) that affect an activity before the externality is generated. But in the past decade researchers have analyzed the ability of what we have called ex post policies (e.g., exposure to tort liability) to control externalities. These latter policies regulate the externality only after it has been generated and harm has occurred. The threat of suit causes the potential injurer to internalize the expected social damages and thus to take optimal precaution.

Economists have generally viewed ex ante and ex post policies as substitutes for correcting externalities. The usual policy recommendation has been to choose the less costly regulatory policy to administer, assuming the policies to be equally effective. For instance, in the case of chopping down a tree in one's yard, it is less costly to use threat of suit to force appropriate caution than to construct a myriad of permits and regulations covering tree-felling. An example at the other extreme is air pollution, where it is less costly to promulgate well-thought-out regulations than to let each injured party take injurers to court. Rarely is the joint use of ex ante and ex post policies recommended for a given externality.[10]

This theoretical conclusion, however, stands in stark contrast to actual policy. One of the most noticeable features of current policy dealing with externality-generating activities in a wide number of areas is that ex ante and ex post policies are very frequently used jointly. Consider the following examples. The potential inefficiencies of incompatible neighboring property uses—e.g., a hospital located next to a noisy, dusty cement-manufacturing plant—are minimized by zoning ordinances (a form of ex ante regulation) and by simultaneously exposing the externality-generator to nuisance liability (a form of ex post regulation). Similarly, society attempts to minimize the harms that new pharmaceuticals may inflict on users by requiring the

10. Professor Shavell appears to be alone in suggesting that ex ante and ex post regulation can complement one another in that their joint use can correct the inefficiencies of using either alone to correct an externality. See, e.g., Steven Shavell, "Liability for Harm *versus* Regulation of Safety," 13 *J. Legal Stud.* 357 (1984) and Shavell, "A Model of the Optimal Use of Liability and Safety Regulation," 15 *Rand J. Econ.* 271 (1984).

manufacturers of drugs to engage in specific tests before the drugs are licensed by the federal Food and Drug Administration for prescription and sale (a form of ex ante regulation) and also by thereafter exposing the drug manufacturers to strict products liability ex post regulation).

This phenomenon of the complementary use of ex ante and ex post regulatory policies is so widespread that the dearth of persuasive theoretical arguments for their joint use is glaring. Various authors have identified inefficiencies associated with one or the other regulatory policy. In the case of ex ante regulation, the typical criticism is that the central regulator has imperfect information on accident costs and damages, which may lead to inefficient under-control of some wrongdoers and over-control of others.[11] The typical criticisms of tort liability have been that suits may not always be brought against injurers, that considerations of the potential injurer's possible bankruptcy corrupt the incentive for taking socially-optimal precaution,[12] and that uncertainty regarding the legal standard leads to over- or under-protection, depending on the circumstances.[13]

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11. See, e.g., William J. Baumol and Wallace Oates, "The Use of Standards and Prices for Protection of the Environment," 73 *Swed. J. Econ.* 42 (1971); Susan Rose-Ackerman, "Effluent Charges: A Critique," 6 *Canadian J. Econ.* 512 (1973); Martin L. Weitzman, "Prices *versus* Quantities," 41 *Quart. J. Econ.* 477 (1974); and Shavell, supra n. 9.

12. Considerations of bankruptcy can lead to either under- or over-precaution by the potential tortfeasor. On the one hand, an otherwise profitable and normal firm that is fearful that an adverse liability judgement could be so large as to drive it into bankruptcy will take more precaution than is required by the legal standard or by other self-interested factors as a means of insuring against bankruptcy. On the other hand, a firm that is struggling to make a profit may attmept to save costs by taking less precaution than is required by the legal standard. It may do so as a calculated gamble. A bankrupt firm cannot pay a large liability judgement. Thus, if an accident occurs and the firm is held liable (an event that is, of course, more likely because of the under-precaution the firm has taken), its limited assets will temper the amount of the judgement against it. Indeed, in the extreme case, a plaintiff who is able to choose among various defendants who may have caused an accident may turn her principal attention to the defendant who has the "deepest pockets"—i.e., who has the greatest financial strength to pay a judgement in the plaintiff's favor—and all but ignore those defendants who (despite their culpability) have few assets.

13. See, e.g., J. P. Brown, "Toward an Economic Theory of Liability," 2 *J. Legal Stud.* 323 (1973); D. Wittman, "Prior Regulation vs. Post Liability: The Choice Between Input and Output Monitoring," 6 *J. Legal Stud.* 193 (1977); R. D. Cooter, L. Kornhauser, and D. Lane, "Liability Rules, Limited Information, and the Role of Precedent," 10 *Bell J. Econ.* 366 (1979); Shavell, *supra* n. 8; R. Craswell and J. Calfee, "Deterrence and Uncertain Legal Standards," 2 *J. Law, Econ, & Org.* 279 (1986); Steven Shavell, *An Economic Analysis of Accidents* (1987); and Robert D. Cooter and Thomas S. Ulen, *Law and Economics* (2d ed. 1993).

Before we can decide on the optimal mix of ex ante and ex post policies for balancing the social costs and benefits arising from the transportation of hazardous materials, we must first review the economic analysis of tort liability. We shall see that there are clearly distinct circumstances in which to impose the two principal forms of liability, negligence and strict liability, and that the circumstances in which hazardous materials are being transported generally argue for the strict liability standard to be imposed on shippers. Then we shall address the issue of the joint use of the sort of ex ante regulations like those contained in HMTUSA and the optimal form of ex post regulation.

An Economic Theory of Tort Liability[14]

Tort liability is a method of assigning financial responsibility for the harms arising in the course of an unintentional, nonconsensual wrong. The actions of the wrongdoer (also referred to as the injurer, the tortfeasor, or the defendant) are evaluated by the court according to one of two general standards—negligence or strict liability. Under the negligence standard, a wrongdoer will be deemed liable for the consequences of an accident if two conditions are fulfilled: (1) his actions were the proximate cause of the victim's (or plaintiff's) injuries, and (2) the defendant breached a duty to take the care that he owed the victim. In essence the second condition means that the defendant failed to take sufficient care or precaution and may, therefore, be said to be "at fault" for this failure. Note that under the negligence standard it is possible for a defendant to be exonerated if his actions were sufficiently careful, even though a victim was injured by his actions.[15] Note, too, that in the event that the wrongdoer takes sufficient precaution to avoid liability, it is the victim who will then have to bear her own losses. This fact should induce potential victims to take sufficient care to minimize this residual liability for their own losses that they might have to bear.

By contrast, under strict (or absolute) liability an injurer will be held liable for the consequences of an accident if his actions were the proximate cause of the victim's harms. There is no level of precaution that, if complied with, will exonerate the wrongdoer from liability if he has proximately caused the harm. Thus, the best that a potential injurer subject to strict liability can hope to do is to minimize the harms that his actions cause; he can fully avoid liability only if accidents do not occur.

The economic analysis of these two tort liability standards begins by assuming

14. This section is based on Cooter & Ulen, supra n. 11.

15. The negligence standard does not always require, but often allows for, an examination of the behavior of the *victim* with regard to precaution. Under the standard known as negligence with contributory negligence, the defendant will be completely exonerated even if she failed to take adequate precaution if the victim also failed to take adequate precaution. Under the standard known as comparative negligence, fault (in the sense of failing to take adequate precaution) on the part of the victim, if the injurer was also at fault, can cause a partial rather than a complete exoneration of the defendant.

that a potential injurer perceives two kinds of costs associated with harms to others—the costs of precaution and the expected costs of accidents. This latter category consists of two elements, the probability that an accident will occur and the severity of the accident, measured in terms of the costs imposed on the victim. Both of these elements are decreasing functions of the amount of precaution that the injurer takes. Therefore, the greater the amount of safety, the lower the probability and the severity of an accident's occurring.

Let us now introduce the general notion of tort liability: a potential tortfeasor knows, we assume, that she might be held liable for the full extent of a victim's losses. (As we shall see, precisely how liability will be determined is dependent on whether negligence liability or strict liability is in effect.) Under these assumptions, the potential tortfeasor attempts to minimize the sum of precaution and expected *liability* costs.[16]

To clarify the results, let us put the argument graphically and mathematically. Let x be the level of the firm's precaution in preventing an accident or reducing its severity.[17] The injurer must pay \$$w$ per unit of precaution, so that his total costs of precaution may be represented by the amount \$$wx$. In figure 1 these costs are shown as the upward-sloping line from the origin. An accident will occur with probability $P(x)$ and will be of severity or cost $A(x)$. The expected accident costs are, therefore, $P(x)A(x)$. Let us define this term as $D(x)$. We assume that these expected costs are convex and downward-sloping over the relevant region of precaution, as shown in figure 1.

The expected social costs of the externality or accident are the sum of the injurer's own precautionary costs, wx, and the expected accident costs, $D(x)$. In the figure these expected social costs are given by the U-shaped curve that reaches a minimum at x^*. Mathematically, this socially optimal amount of precaution, x^*, is that which minimizes these social costs, i.e.,

$$x^* = min[wx + D(x)]$$

At the unique level of x that minimizes this equation, the marginal expected cost

16. We are also ignoring the important category of administrative costs. Included in these costs would be each party's litigation expenses and the court's costs. The exclusion of administrative costs will not greatly affect our fundamental conclusions about the efficiency of the different tort liability standards. Generally speaking, the administrative costs of strict liability are less than those of negligence. But while this may be true for any given case, more cases may be litigated under a strict liability standard precisely because it is less expensive for a plaintiff to bring an action under that standard. Thus, total administrative costs—the costs of each case times the number of cases—may not be so different under the two liability standards.

17. For simplicity, we will not consider the decisions of the potential victim by assuming she always takes the socially-optimal level of precaution.

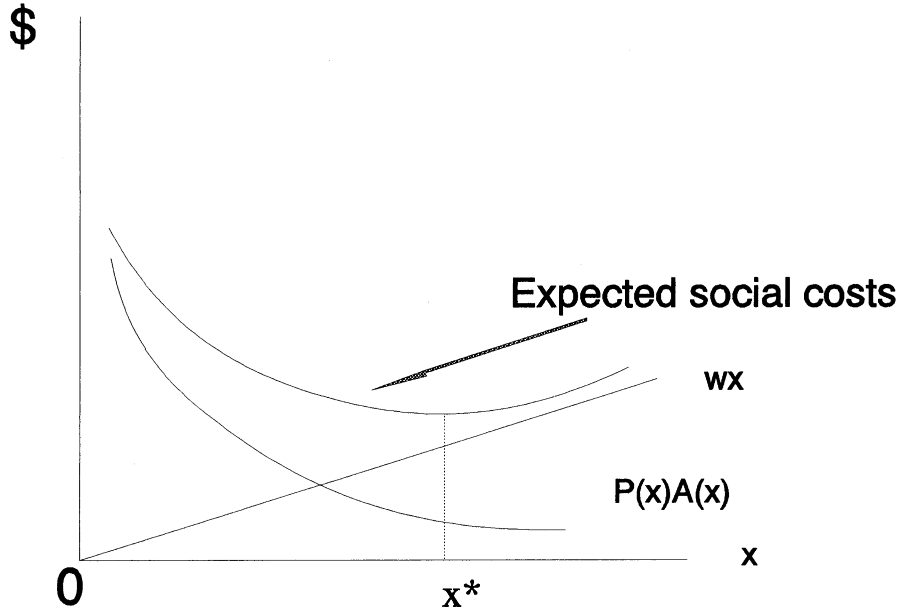

Figure 1. Expected Social Costs of Accidents

of precaution equals the negative of the expected marginal cost of the accident, i.e.,

$$w = -D'(x)$$

We have been speaking thus far in terms of expected *social* costs and not in terms of expected *liability*. We must now introduce the tort liability system standards in order to see which standard is most relevant to the sorts of harms that arise in the transportation of hazardous materials.

Let us define negligence liability as the standard that applies when it is the case that the actual amount of precaution taken by the potential tortfeasor is *less than* the amount required by the legal standard of care. If the actual amount of precaution taken is *greater than* the legal standard, there is no liability. In figure 2 let x^+ represent the legal standard of care. We can then see that the *expected liability* curve (represented by the darkened line) follows the expected social cost curve down to the level of x^+ and then drops down to the *wx* or precaution-cost line. There is, then, a sharp discontinuity in the expected liability curve at the legal standard of care, x^+.

If the potential tortfeasor's goal is to minimize his expected liability costs when faced with a negligence standard, he will take precaution exactly equal to the legal standard of care, x^+. It follows that the negligence standard will induce potential tortfeasors to take the socially-optimal amount of precaution *only if the legal standard of care is set equal to the socially-optimal level of care.* In terms of figure 2, only if

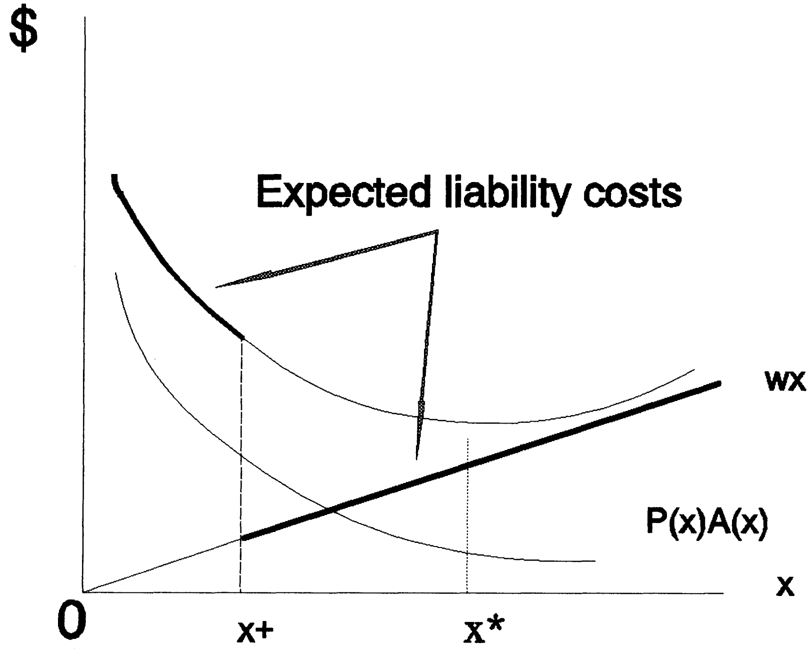

Figure 2. Negligence Liability

$x^+ = x^*$ will the negligence standard induce optimal precaution.

There is another condition that must be met in order for negligence to work just right. That is that the precautionary technology must be *bilateral*. By this we mean that there are meaningful actions that each party can take to reduce the probability or severity of an accident. An example would be pedestrian-automobile accidents: pedestrians can reduce the probability or severity of such harms by taking care to cross only at designated crosswalks, by looking both ways before stepping into the street, by wearing reflective clothing at night, and so on; automobile drivers can reduce the probability and severity of these accidents by obeying traffic signals and all other relevant rules of the road, maintaining their cars in good condition, paying attention, and so on.

What's the connection between the optimality of negligence and bilateral precaution? Recall that under negligence both the potential victim and the potential injurer may be held liable for the entire amount of the victim's losses. The potential injurer can evade this responsibility by complying with the legal standard of care; if he thus evades liability, then the potential victim will bear residual liability for her own losses. In that case, the best thing for her to do is to take enough precaution to minimize her own losses. Clearly, it is sensible to shift the possibility of liability back to the potential victim only if there is something that she can do to reduce the probability or severity of an accident.

What are the efficiency considerations regarding strict liability? Recall that under

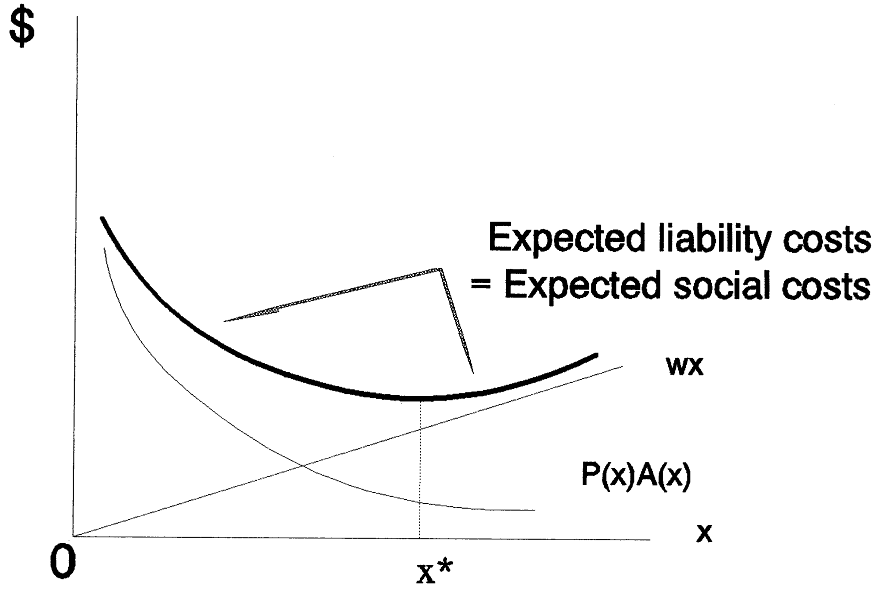

Figure 3. Strict Liability

that standard an injurer is liable for the victim's losses if the injurer proximately caused them. There is no exonerating level of care. What this implies is that under strict liability the expected social cost curve is identical to the expected liability curve, as shown in figure 3. Thus, in minimizing expected liability, the potential tortfeasor is also minimizing expected social costs: x^+ accomplishes both goals.

Strict liability will lead to efficient precaution by the injurer and the consequent minimization of the social costs of accidents under two conditions: (1) the victim receives perfect compensation, and (2) the technology of precaution is unilateral. Perfect compensation occurs when the victim receives a sufficient sum of money in the event of an accident so that she is indifferent between not having had the accident and having had the accident plus the sum of compensatory money damages. In practice what this means is that the true accident costs, $A(x)$, must also be the actual amount of accident costs assessed against the injurer. If the amount awarded by the court is either more or less than this amount, potential injurers may be induced to take correspondingly too much or too little precaution. As to the technology of precaution, it is said to be unilateral when only one party may realistically take action to reduce the probability or severity of an accident. An example would be many commercial airline accidents: only the airline or the manufacturer can meaningfully take precautionary action to reduce the probability or severity of an accident; there is almost nothing that a passenger or, more dramatically, an innocent bystander on the ground, can do in that regard.

The Theory Applied to Harms Arising in the Transportation of Hazardous Materials

How does this analysis of the distinction between negligence and strict liability apply to the case of personal and property injuries arising from the transportation of hazardous materials?[18] In terms of the characteristics we identified above, we may divide accidents involving the transportation of hazardous materials into two groups—those in which the technology of precaution is clearly bilateral and those in which it is clearly unilateral. (We also recognize that there may be accidents involving the transportation of hazardous materials in which it may be very difficult to characterize the technology as more bilateral than unilateral or *vice versa*. Below we address what might be done in those circumstances.)

Consider, first, accidents in which precaution is unilateral. As a paradigm of these accidents, imagine a railroad car that inadvertently spills a hazardous substance onto the property of a farmer living beside the railroad tracks. Precaution is unilateral in this instance because there is a great deal that the potential injurer, i.e., the shipper and the carrier, could have done to minimize the probability and severity of this accident and virtually nothing that the farmer could have done. Strict liability would be the more appropriate liability standard here.

Consider, next, accidents involving the transportation of hazardous wastes in which the technology of precaution is bilateral. Suppose, for example, that the accident involves injury in a train yard: a car containing a hazardous substance begins to leak while being transferred from the control of one carrier to another.[19] Here there is something that either party could have done to reduce the probability or severity of an accidental release of the hazardous material. The original shipper could have taken care that the car in which the material was transported was in good shape, that all valves were functioning, that the car was clearly marked as containing a hazardous material, and that all who might handle the shipment were on notice that the car contained a dangerous substance. For its part, the transferring railroad could have taken care that the car containing the dangerous substance was not bumped or in other ways mishandled, that its employees were competent to deal with cars of that type and trained to deal with emergencies, and so on. Because there is something that both

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18. For the only other treatment of this topic of which we are aware, see Akihiro Watabe, "Liability Rules and Hazardous Materials Transportation," 25 *Transportation Science* 157 (1991).

19. The example is based on *Indiana Harbor Belt Railroad Company v. American Cyanamid Company*, 916 F.2d 1174 (7th Cir., 1990). A railroad tank car temporarily under the control of the plaintiff-railroad but belonging to the defendant-chemical company leaked acrylonitrile, a class 5 hazardous material. At issue was the appropriate liability standard to use in determining who should be responsible for decontamination measures totaling almost $1 million. Judge Posner, correctly, in our view, argues for negligence, but he does so on grounds that are different from those we espouse here.

parties could have done to minimize the probability or severity of an accident, the appropriate liability standard to impose in this type of setting is negligence.

As another example of an accident involving hazardous materials in which precaution is bilateral, consider an accident involving a motorist and a truck containing a hazardous material. Clearly there is something that each party can do to reduce the likelihood or seriousness of an accident: the truck should follow all the rules of the road, carry signs about the flammability and other dangers of its cargo, take the most appropriate route (given considerations of speed, density of population, and the like), and so on; similarly, the motorist should also obey all traffic rules and take appropriate steps to avoid accidents.

These considerations suggest that accidents involving the transportation of hazardous materials ought to be considered under two different liability standards, depending on the circumstances of the accident. If the technology of precaution may be characterized as bilateral in the sense that there was something that either party could have done to reduce the probability or severity of an accident, then the appropriate standard is negligence. However, if the technology of precaution is more clearly unilateral in that only the defendant-injurer could have realistically taken steps to reduce the likelihood or seriousness of the accident, then strict liability is the more appropriate liability standard.

For the sake of completeness, we ought to say a word about what is to be done when it is not entirely clear whether precaution is bilateral or unilateral. In those instances, the more appropriate standard is negligence. The reason for preferring negligence to strict liability when there is doubt about the technology of precaution is that the harm that results from imposing negligence in a situation in which strict liability is really the better standard is less than the harm that results from imposing strict liability in a situation in which negligence is really the better standard. In the former instance there is nothing that the plaintiff-victim could really have done to minimize the probability or severity of the accident. Subjecting people in those circumstances to scrutiny under the negligence standard will not induce them to take precaution that they cannot really take. But in the latter instance, if a plaintiff-victim who could take precaution is relieved of the duty to do so, that may induce potential victims inefficiently to forego actions that they ought to take.[20]

Our recommendation may seem to make the determination of liability for harms arising from the transportation of hazardous materials too contingent. Some might argue that it is better to have a single, certain standard than one that is determined by an arcane concept such as the nature of the technology of precaution. We believe that our proposal is better for all concerned—for potential victims and for shippers and carriers. First, the proposal takes account of the very real differences that are likely to exist in the transportation of hazardous materials. A single shipment could well present individuals and organizations with differing situations—some in which they

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20. The social costs of getting the liability standard wrong can be considerable. As an example, consider the crises in products liability and medical malpractice. See Peter Huber and Robert E. Litan, eds., *The Liability Maze: The Impact of Liability Law on Safety and Innovation* (1991).

alone can take action to prevent harm and some in which they *and* potential victims can take action. For instance, the same railroad tank car could be defectively maintained before it is loaded, handled negligently by a railroad in the course of shipment, struck at a rail crossing by a negligent driver, or leak onto the property of neighboring farmers. Several of these situations ought to be evaluated according to a negligence standard and some according to a strict liability standard. It would be a mistake to try to fit these disparate types of accidents involving the transportation of hazardous materials into a Procrustean bed of a single liability standard. Second, the care that it is appropriate for a shipper or handler or potential victim to take should be socially optimal (and the administrative costs of determining liability should be optimal) so long as these differences between bilateral and unilateral precaution are recognized. Consider the error that would flow from *always* holding a shipper or carrier strictly liable, even if the potential victim had been able to take precaution. Shippers and carriers would be obliged to take extraordinary precautionary actions or establish self-insurance funds to protect themselves against the increase in the incidence of being held liable. Potential victims would feel absolved from having to be as careful as they would be if they were wholly or partially liable for losses their own carelessness caused. Neither of those outcomes is desirable.

The Efficiency of Tort Liability Under Uncertainty

The results of the section above in which we abstractly considered the efficiency of the two liability standards implicitly assumed that there was certainty about all the relevant variables among all the economic decision makers. In reality, this is not the case. For example, a potential tortfeasor cannot be certain how a court will evaluate the precaution he has taken vis-a-vis the legal standard of care. He might believe himself to be complying with that standard only to discover that the court deems him liable anyway. Similarly, under strict liability the potential tortfeasor faces uncertainty about the extent of the damages that the court will award a successful plaintiff and about whether the court will find the defendant's actions to have been a proximate cause of the harm. And finally, in view of our recommendation of the last section, the potential tortfeasor and potential victim cannot be certain prior to the actual accident whether the court will judge their actions according to a negligence standard or a strict liability standard. The question that all these forms of uncertainty present for our previous conclusions is, "How is the efficiency of the tort liability standards affected by the presence of uncertainty about important legal variables?"

For the sake of brevity, let us confine our analysis of the effect of uncertainty on the efficiency of the ex post liability standard to negligence.[21] To simplify matters further, let us also assume that the only form of uncertainty with which we will be concerned is the potential tortfeasor's uncertainty about how the court will evaluate

21. A discussion of the effect of uncertainty on the efficiency of strict liability would reveal conclusions similar to those we derive in the text for the various forms of negligence.

his actual level of care with respect to the legal standard of care. Let us introduce the injurer's subjective probability distribution around the legal standard of care, x^+, and call this distribution $q(x)$. Assume that $q(x)$ is a continuous probability density with support $[0,\infty]$. The probability that the injurer's actions will be deemed not to have satisfied the legal standard of care and the injurer held liable to the victim is given by

$$R(x) = \int_x^\infty q(x)dx$$

Thus, $R(x)$ is the probability that the injurer will be held liable to pay compensatory damages, given that the injurer has taken precaution in the amount x.

How will the injurer respond to this form of uncertainty under negligence? The injurer now is attempting to minimize the sum of precautionary costs and expected liability costs, with $R(x)$ now replacing $P(x)$ from before:

$$x^* = \min[wx + A(x)R(x)]$$

It can be shown that if the total cost function associated with this formulation is strictly convex, then there is indeed a unique minimum, x^*. The first-order condition for the minimization is

$$w + A'(x)R(x) - A(x)q(x) = 0.$$

This equation is fundamental to our analysis of the effect of uncertainty on the efficiency of the negligence standard, so let us take a moment to comment on the terms in that equation. The first term is simply the marginal cost of a unit of precaution. The second and third terms sum to the expected marginal liability costs of a unit of precaution and consist of two distinct effects. The first of these terms, $A'(x)R(x)$, is the marginal accident cost times the probability of being held liable for the accident if the injurer has taken precaution equal to x. This term, which we call the "injury effect," is negative because, by assumption, $A'(x)$ is negative and $R(x)$ is always positive. But there is also a saving from providing slightly higher precaution, in that the probability of being held liable is reduced. This saving is captured in the term $[A(x)q(x)]$. This term, which we call the "liability effect," is positive because $A(x)$ is positive and, by assumption, $q(x)$ is positive.

Ultimately the question is whether the level of precaution chosen by the injurer under this form of uncertainty is greater than, less than, or equal to the socially-optimal level of precaution. A complete answer would require making further assumptions about the relevant components of the expected cost function and is beyond the scope of this paper.[22] For our purposes here, the most important assumptions concern the nature of the distribution $q(x)$ and whether there is ex ante regulation.

With regard to the distribution of $q(x)$, if we assume a mean-preserving spread, with the mean centered on the socially-optimal level of precaution, an increase in the uncertainty regarding the court's evaluation of the injurer's precaution vis-a-vis the

22. See Kolstad, Ulen, and Johnson, supra n. 8, for the complete answer.

legal standard of care translates into the potential tortfeasor's having an increase in the variance of $q(x)$ around the socially-optimal level of precaution. This characterization leads to two propositions. First, this increase in legal uncertainty will result in potential injurers *reducing* their levels of precaution below the social optimum. Second, if it happens that potential injurers' subjective probability distribution, $q(x)$, does not exhibit increased variance but is biased in the sense of its mean falling below the socially-optimal level of precaution (as could happen if there have been a large number of suits about this sort of harm but none has been successful), then potential injurers will again take too little precaution.[23]

The Relationship Between Ex Ante and Ex Post Regulation

We have just asserted that the ability of the negligence standard to induce socially-optimal precaution by a potential tortfeasor may be lessened by the presence of a highly-likely form of legal uncertainty. Exactly the same conclusion holds for a potential tortfeasor who faces a strict liability standard. These conclusions raise two questions:

1. If we subject the potential tortfeasor to ex ante administrative agency regulations at the same time that we subject him to an (uncertain) ex post

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23. A possible corrective to these problems is to alter the standards by which proximate cause is to be determined. This was a tack adopted in the 1983 Minnesota Environmental Response and Liability Act (MERLA). A section of that act outlined four conditions that, if met, would allow the court to infer that the defendant had proximately caused the plaintiff's harm. One of those conditions allows liability to attach if "the death, injury, or disease suffered by the plaintiff is caused or *significantly contributed to* by exposure to the hazardous substance" (M.S.A. §115B.07(d)) [our italics]. Another section states that evidence to a "reasonable medical certainty"—the usual standard in tort liability cases—that the exposure to hazardous or toxic wastes caused or significantly contributed to a plaintiff's injury is *not* required in order to submit the case to a jury.

Our feeling is that this sort of corrective is not advisable. There are many reasons for this feeling; one is that it establishes an exception to the usual standards that is almost impossible to defend. If the state of scientific knowledge is insufficient to establish proximate cause from exposure to hazardous materials with the same degree of accuracy that it is for other tortious wrongs, why may we not simply relax the plaintiff's burden of proof on causation in all other instances of inadequate scientific knowledge? As we shall see in the next section, *ex ante* administrative agency regulation can be used complementarily with strict liability to provide a far more defensible corrective.

See Gary V. Johnson and Thomas S. Ulen, "Designing Public Policy toward Hazardous Wastes: The Role of Administrative Regulations and Legal Liability Rules," 68 *Am. J. Agric. Econ.* 1266 (1986).

liability standard, can he thereby be induced to take the socially-optimal amount of precaution?

2. And if so, at what level of precaution should the ex ante administrative agency regulations be set?

As we have seen with respect to the HMTUSA, ex ante administrative agency regulation typically specifies a minimally-acceptable level of precaution. We assume that there is no uncertainty with regard to the regulatory constraint; that is, the potential injurer and the regulatory agency know the level of the constraint and that it is enforced with certainty. How does information about the ex ante safety regulation influence the injurer's perception about his obligations to take care to minimize his expected liability costs when there is legal uncertainty? The injurer knows that the appropriate amount of precaution cannot be less than the minimum standard set by the statute or administrative agency. But the injurer may also perceive the appropriate amount of precaution commanded by the liability system to be significantly greater than that compelled by the regulation. This seems most closely to approximate the prevailing relationship between ex ante and ex post regulation where they are jointly used. For example, no court today accepts compliance with a regulatory agency standard as a complete or mitigating defense in a strict liability tort action.

The injurer will not consider adopting a level of precaution below the minimum established by ex ante regulation. In effect, the presence of the ex ante standard truncates the injurer's subjective probability distribution, $q(x)$, at that minimum.[24] (Recall that $q(x)$ relates levels of precaution, x, to the likelihood of being held liable.) The result is that the imposition of an ex ante regulatory standard, given the existence of a causally-uncertain strict liability standard, will promote efficiency if the injurer would have taken too little precaution if subject *only* to ex post tort liability. Specifically, the higher the level of the ex ante regulatory standard, the higher the appropriate precaution under strict liability is likely to be, at least in the eyes of the injurer. Thus, the ex ante regulation can correct cases of under-precaution resulting from exposure to liability alone.

In summary, the optimum level of an ex ante safety regulation, given that an ex post liability standard also exists, will generally be *less than* the socially-optimal level of precaution, x^*. The implication of this result is that where optimal precaution calls for the joint use of ex ante regulation and an ex post liability rule, the optimal ex ante regulatory constraint should be set *below* the socially-optimal level of care.

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24. There are a number of assumptions that we could plausibly make about the firm's new truncated subjective distribution on the legal standard, $\underset{\sim}{q}(x)$. As explained more fully in Kolstad, Johnson, and Ulen, supra n. 8, our remaining results on the optimal relationship between ex ante and ex post regulation hinge on the relationship between $q(x)$ and $\underset{\sim}{q}(x)$. We take a Bayesian approach, making a simple and direct assumption that $\underset{\sim}{q}(x)$ has a distribution conditional on $x \geq$ *the minimum safety standard*. In other words, the probability mass that previously lay below the standard in $q(x)$ is now distributed above that standard.

CONCLUSIONS FOR PUBLIC POLICY TOWARDS THE TRANSPORTATION OF HAZARDOUS MATERIALS

The propositions presented above have profound implications with regard to the conditions where ex ante regulation alone or both ex ante regulation and ex post liability should be used jointly in a wide range of public policies for dealing with external costs. We concluded that the joint use of ex ante and ex post regulation will enhance efficiency if there is uncertainty in the determination of liability. Only if the determination of liability is perfectly accurate, should ex ante and ex post regulation be used separately.

One of our strongest conclusions, and a startling one, is that when ex ante and ex post policies should be used jointly, efficiency generally requires that the ex ante regulatory standard be set at a level that, if regulation were used alone, would provide a socially-suboptimal level of safety or precaution. Put somewhat differently to emphasize this unconventional conclusion, when tort liability rules are in place, it is inefficient to set ex ante regulatory standards at the socially-optimal level. The only instances when the ex ante regulatory standard should be set at the social optimum are when there is no ex post liability or, equivalently, when there is a zero probability of a judgment against a rational injurer under ex post liability.

The application of these conclusions to the issue of the optimal public policies towards harms arising from the transportation of hazardous materials is straightforward. There *is* tort liability for such harms, and we have recommended a method for determining whether the liability standard should be one of negligence or strict liability. But even if our recommendation were followed to the letter, there would still be uncertainty of some variety attending the imposition of ex post liability. The appropriate standard to use might be unclear, the amount awarded in compensation might be too much or too little, the court's perception of the parties' precautionary actions vis-a-vis the legal standard might be very different from the parties' own perceptions. In those instances, relying on ex post liability alone to induce optimal precaution would be a mistake. Tort liability should be supplemented with ex ante regulatory standards. However, these standards should be set below the socially-optimal level of precaution. The purpose of these standards is simply to set a floor that will truncate potential injurers' subjective probability distribution on liability so as to induce them, on their own, to take precaution beyond the minimum required by statute or by an administrative agency.[25]

If this analysis of the optimal mix of ex ante and ex post policies is correct, then our current method of inducing safety in the transportation of hazardous materials could stand improvement. Thus far, we seem to be relying almost exclusively on the sorts of regulatory standards laid down in HMTUSA to determine the socially-optimal amount of precaution to take with respect to hazardous materials transportation. A

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25. We are, of course, aware of the fact that enforcement of the statutory or administrative agency minimum safety standard may also be stochastic.

better way would be to ease the regulatory oversight on shippers and carriers and encourage ex post liability for those shippers and carriers who do, in fact, cause harm.

16

ANNUAL LICENSE FEES AND OTHER CHARGES FOR ROAD TRANSPORTATION OF HAZARDOUS MATERIALS

Leon N. Moses and Ian Savage

ABSTRACT

In September 1992 the United States Department of Transportation imposed a $300 annual fee on motor carriers of certain kinds of hazardous materials. The revenue raised will be used to pay for training emergency response personnel. Econometric analysis suggests that accident risk varies significantly depending on the size and type of carrier, and the particular hazardous commodity hauled. An improved system of licenses and other charges which takes these factors into account in determining what should be paid by individual carriers would provide greater incentives for safe operation.

INTRODUCTION

The Hazardous Materials Transportation Uniform Safety Act of 1990 (HMTUSA) gave the United States Department of Transportation (DOT) broad powers to set fees for transporting hazardous materials based on the type of material, the level of "threat to property, persons, and the environment," and the proportion of a firm's business that involves the transportation of hazardous materials. However, in September 1992 the DOT chose to set a fixed fee of $300 for firms that transport: radioactive materials, over 25 kilograms of class A or B explosives, packages of more than one liter of substances that are extremely toxic by inhalation, and bulk or large packaged shipments emanating from one shipper.

The main purpose of this paper is to evaluate this fee system and propose changes in it that would more faithfully carry out the intent of HMTUSA in the mandate that was given to DOT by Congress. The paper is divided into three parts. The first contains a brief theoretical statement on what economists would view as an optimal system of fees for the transport of hazardous materials. It examines the various costs associated with a hazardous materials accident.

Part two of the paper uses multivariate regression analysis to show that accident rates vary significantly depending on the characteristics of firms and the specific commodity carried.

Part three proposes a fee structure that the authors believe would be an improvement over the present flat fee system. The preferred structure employs a differential annual fee based on past accident experience of different kinds of firms and the materials they transport, a user charge that covers the variable cost of cleaning up a particular spill, and a charge for environmental damage.

1. THE COSTS OF HAZARDOUS MATERIALS ACCIDENTS

In an ideal world trucking firms would have to bear all of the costs of an incident for which they are at fault, some directly and some indirectly. Firms would then be able to make informed tradeoffs between the costs of investments that prevent accidents, such as improved driver training and high standards of vehicle maintenance, and the full costs of accidents. With such internalization of accident costs the optimal, that is to say economically efficient, number of accidents would occur. Economists would argue that the reason there may currently be an excessively large number of accidents and a "truck safety problem" is that carriers do not have to bear all of the costs associated with accidents. We turn now to a review of these costs.

The costs of truck accidents fall into four broad categories. The first of these costs are internal to the firm. They entail such things as: the cost of repairing or replacing vehicles; health benefits for drivers or death benefits to drivers' families; restitution to shippers for damage to or loss of cargo; and loss of goodwill and a decline in revenue because shippers are knowledgeable about the quality of service offered by different firms and are likely to avoid those that have many accidents. If a motor carrier is involved in an accident that is caused by another party, the costs of the accident should be recovered from that party and/or its insurance company. If the trucking firm is at fault and cannot recover costs from another party, then these costs are internalized by the motor carrier. They are internal even when they are covered by the trucking firm's own insurance because firms that have a high accident rate find that their insurance premiums or the amount of money that they must put into a private fund increases. The trucking firm has every incentive to invest in safety up to a point where its private marginal cost of achieving safety is just equal to the marginal benefit it derives from such investments. This being the case there is no need to include these costs in a government imposed system of license fees and user charges.

The second category of costs involves identifiable individuals who are not shippers or carriers. They are third-party individuals and organizations, such as other road users and owners of property adjacent to highways, who may be injured in an accident or have their property damaged. At present there is also no need to include these costs in a system of government fees and user charges. Injured individuals can recover damages through legal torts from parties at fault. Although the tort system is not perfect, motor carriers have a strong incentive to take the accident awards and litigation costs into account when designing safety investment programs. Even if settlements are covered by insurance, carriers have an incentive to keep insurance premiums to a minimum.

The third category of costs is quite similar to that we have just described, but in this case the damage is to the environment and broad groups of individuals. Rivers may become polluted, fish and other wildlife may be killed, and valuable plants and trees destroyed. The air and groundwater may become polluted. Some of the cleanup costs, such as hiring contractors to remove contaminated soil and debris and taking it to waste depositories, may be recovered directly from motor carriers or other at-fault parties, or litigation can be instigated citing the provisions of such laws as the Clean Water Act of 1977 or the Resource Conservation and Recovery Act of 1976. However, courts may be unwilling to make awards to parties too far removed from an accident site, and it is often the case that cleanup costs are borne by public agencies. Other costs may be difficult to quantify, may affect many unidentified victims, or may be difficult to substantiate in a legal action. A large number of individuals in an affected area may have to be evacuated and spend days away from home at some expense to themselves. Businesses in the vicinity may suffer temporarily reduced revenues. An accident may also require that all traffic in the vicinity of the accident be delayed and/or rerouted to an alternative, longer route. To ensure that firms have the correct incentives to provide safe operation, the full societal and environmental costs should be recovered from parties at fault.

The final category of costs that result from an accident are associated with the response of public agencies such as fire department personnel who are the first responders, police officers who control traffic at the scene of an accident and assist in the evacuation of people in the immediate area, and the provision of publicly provided emergency medical service. Most of these costs are different from those described above. The first three categories of costs are only incurred when an accident occurs. If there is no accident then there are no costs. In contrast, many of the public costs of emergency response exist whether or not there are accidents. In a sense they are fixed costs.

It might be argued that fire and police service is normally provided, and that there is therefore no need to burden trucking firms with additional fees since they already pay local property taxes at their bases of operation. However, there are identifiable additional costs for fire and police departments if they are to respond adequately to hazardous materials truck accidents.

Many serious truck accidents occur on the open road away from urban areas. Unlike fire departments of large urban areas that have experience in dealing with chemical and other industrial fires and accidents, few rural fire and police departments have such experience. They are accustomed to dealing with domestic and agricultural fires, and routine road accidents. They are often staffed by volunteers. There are identifiable additional costs that such departments will incur if they have to respond to spills of hazardous materials, accidents that produce emissions of poisonous gases, etc.

Rural fire and police personnel will have to receive special training if they are to recognize and deal with the specific hazards that particular commodities pose. The emergency response guides published by the United States and Canadian governments indicate the necessity for training of response personnel. These training costs are of a recurrent nature since first responders must be continually updated on the new hazardous and toxic materials being developed by industry, and new and improved methods of dealing with them. It is the purpose of the license fee to allow grants to be made by the federal government to allow training and response planning by local authorities.

There are also costs involved in upgrading the equipment owned by local fire and police departments. Responding to hazardous materials truck accidents clearly involves the use of equipment that is unnecessary for dealing with domestic fires and routine highway accidents. Some hazardous commodities require standards of protective clothing higher than those normally used by fire departments. There may also be the need for lime, soda ash, and dry chemicals to be held in stock as extinguishing agents. It may no longer be possible to rely as fully on volunteers as in the past. Rural fire departments may have to hire some number of professionally trained, full-time staff. Economists normally view labor as a variable cost. However, that is not the case here. The cost of full-time labor will be incurred when the personnel are standing ready to respond to an accident as well as when they are actually coping with one. HMTUSA does not have any provision for using license fees to provide funding to local authorities to purchase specialized equipment or expand numbers of staff.

In an ideal world the costs of emergency response would be passed on to parties that cause hazardous materials accidents, be they motor carriers or other road users. Any variable costs incurred in the response of emergency services, such as overtime payments, attendance fees for volunteer departments, or the use of extinguishing materials, should be billed directly to the trucking firm if that firm is at fault. The bill should be sent to the other road user if that user causes an accident involving a truck carrying hazardous materials.

The recurrent cost of additional equipment and training needs to be paid from a central fund. Some fraction of this fund should be raised from the trucking industry in the form of an annual license fee. The proportion paid by the industry should be related to the proportion of accidents in which a truck rather than another road user is at fault. The balance of the fund should be derived from other road users by use of general tax revenues, a supplement on annual automobile registration fees, or a tax on insurance premiums. For the fraction of the fund raised from the trucking industry, a rational system should have the annual license fee paid by individual carriers be proportional to the actuarial risk posed by that type of carrier and the commodity carried. If there is evidence that accident rates vary according to different classes of carriers and the commodities they haul, then the flat $300 fee proposed by DOT is inappropriate. The next section of the paper investigates the evidence for differential risk.

2. EVIDENCE ON DIFFERENTIAL RISK

Accident Risk of Hazardous Material Carriers

In an earlier paper, the authors presented an analysis of the characteristics of carriers of hazardous materials and their accident performance (Moses and Savage, 1992). The data used in the investigation were derived from initial "Safety Review" audits of U.S. interstate motor carriers. These audits are mandated by the 1984 Motor Carrier Safety Act. In the course of these audits, data are collected on firms' physical characteristics, types of goods carried, accident record, and compliance with federal motor carrier safety regulations. We obtained the entire database of firms that were audited between October 1986 and November 1991. When cleaned up, the dataset contained 75,577 firms of which 13,498 (18%) indicated that they carried hazardous materials.

Using Poisson regression techniques, we were able to determine that carriers of hazardous materials had a higher accident rate than those that did not transport these goods. Firms that carried hazardous materials exclusively had an accident rate 11% higher than comparable firms that did not carry these commodities; they had a rate of fatalities and serious injuries that was 22% higher. Firms that carried hazardous materials as well as general freight had an accident rate that was 18% higher, and a fatality and injury rate that was 24% higher, than the rates of two kinds of firms: (1) those that do not carry general freight or hazardous materials, and (2) firms that carry one of the above but not the other.

When this information on accident frequency is combined with the knowledge that hazardous materials accidents require specialized firefighting training and equipment, it is clear why hazardous materials carriers should pay a supplemental annual license fee. They require more emergency response facilities and call on them relatively more frequently than other carriers.

Accident Risk of Different Types of Carriers and Hazardous Materials

We now turn our attention to the 13,498 firms that indicated they carried hazardous materials. A multiple regression model is used to explain the effect on accident rates of firm size, other characteristics, and the specific hazardous materials hauled. This information is used as a basis of a proposed license fee system that improves on the one that DOT has adopted.

Poisson regression techniques are employed to explain two measures of accident occurrence. One is the number of "reportable accidents" that a firm experienced in the 365 days prior to the audit. Reportable accidents are defined as accidents involving a fatality, an injury, or more than approximately $5,000 in property damage. Many accidents that involve small amounts of damage are not included in this database. The second measure of accident occurrence is the number of fatalities and serious injuries associated with the above mentioned accidents. The latter represents a measure of the severity of the accidents. Explanatory variables were firm size measured by annual fleet miles, the percentage of drivers involved in trips over 100 miles, a dummy variable for private carriage, a dummy variable representing an unsatisfactory audit rating, and dummy variables for different categories of hazardous materials. The appendix to the paper describes the Poisson regression technique and gives more details on the variables employed.

Before describing the results, there are some data problems that must be explained. The first is that data do not exist on the amount or proportion of a firm's business that each hazardous material represents. Firms do, as part of the audit, complete a "census" form where they identify which of 25 categories of non-hazardous goods and 21 sub-categories of hazardous goods they carry. They also indicate whether the hazardous material is carried in tanks or packages or both. They can classify themselves in as many categories as they wish. The data only permit the determination of whether a particular hazardous material is carried or not.

The second problem is that firms routinely carry several of the 21 categories of hazardous materials, and often do so in both tanks and packages. Thus any econometric analysis that used dummy variables for all possible categories of hazardous material and type of packaging would run into a severe problem of collinearity. We decided to consolidate the potential 42 categories, 21 hazardous materials and 2 kinds of packaging, into 9 categories. A correlation table was used to decide the aggregations. After the consolidations were carried out, we found that on average firms carried 1.6 of the 9 categories. The 9 categories are: explosives, liquids in tanks, liquids in packages, gases in tanks, gases in packages, poisons, radioactive materials, hazardous wastes, and an "other" category.

The regression results are shown in table 1. The coefficients are interpreted under two headings: firm characteristics and the commodity carried.

Firm Characteristics. Accident rates decline with firm size. The coefficient on total fleet miles has a value significantly less than unity in both of the regressions. This result means that accidents increase less than proportionately with miles, i.e., the rate of accidents declines with size. In practical terms, accident rates of firms that travel 1 million miles a year are 23% below those of very small firms, i.e., those that operate 5,000 miles per annum. Firms with annual mileages of 5 million have accident rates 27% below those of the very smallest firms. Fatality and injury rates decline more slowly with size. Firms with annual mileage of 5 million have fatality and injury rates about 17% below those of the very smallest firms.

Long-distance operations are associated with higher accident rates. Long-distance operators are defined as firms whose drivers are all involved in trips that exceed 100 miles. They have a total accident rate that is 22% higher than firms that are exclusively involved in short-distance operations, and a rate of fatalities and injuries that is 53% higher. This result is not surprising. The measures of accidents used in this analysis exclude the minor damage-only incidents that frequently occur in congested urban areas. Higher speeds that occur on the open road result in accidents that are more serious in terms of fatalities, serious injuries, and property damage. This result reinforces our earlier comment that emergency response training is particularly needed by fire and police departments in rural areas.

Private carriers appear to have accident rates that are about 30% lower than those of comparable for-hire carriers. This is true for both reportable accidents, and fatalities and injuries.

Firms that are rated unsatisfactory in government safety audits have reportable accident rates that are 50% higher than firms rated conditional or satisfactory, though these accidents do not result in a higher incidence of fatalities and injuries.

These findings are particularly pertinent, given that different types of hazardous materials are hauled by different kinds of trucking firms. In table 2 a comparison is made of the leading characteristics of the firms that haul the various hazardous materials. There are a number of notable features. The first is that radioactive materials,

Table 1: Multiple Regression Analysis of Hazardous Materials Carriers

Dependent variable	Reportable Accidents	Fatalities & Injuries
Audit Dates	All Audits	Before 11/1/90
Observations	13,498	11,732
Proportion of Variation Explained	0.86	0.74
Log-Likelihood	- 11,659	- 9,547
Log-likelihood (log of miles and constant)	- 11,904	- 9,790
Explanatory variables (with t statistics in parentheses)		
Constant	-13.680 (169.65)	-14.393 (142.97)
Log of Total Fleet Miles+	0.954 (9.00)	0.973 (4.20)
Percent of Drivers Employed on Trips over 100 Miles	0.204 (7.37)	0.423 (11.71)
Dummy Variable - Private Carrier	- 0.294 (12.07)	- 0.409 (13.16)
Dummy Variable - Explosives	0.015 (0.65)	0.011 (0.37)
Dummy Variable - Liquids in Tanks	0.071 (2.94)	0.086 (2.92)
Dummy Variable - Liquids in Packages	- 0.019 (0.77)	- 0.015 (0.48)
Dummy Variable - Gases in Tanks	- 0.169 (4.23)	- 0.038 (0.81)
Dummy Variable - Gases in Packages	0.115 (5.54)	0.099 (3.95)
Dummy Variable - Poisons	0.025 (1.07)	- 0.002 (0.08)
Dummy Variable - Radioactive	0.205 (7.60)	0.033 (1.00)
Dummy Variable - Hazardous Wastes	- 0.133 (5.34)	- 0.178 (5.70)
Dummy Variable - Rated Unsatisfactory	0.425 (8.29)	0.002 (0.03)

+ The coefficient on miles is compared against 1 so as to determine the effect of fleet miles on accident rate per mile.

explosives and poisonous materials are hauled by the very largest carriers, with an average size two or more times the overall mean in terms of fleet miles. These firms are also more likely to be general freight firms; they carry hazardous materials as well as other commodities, perhaps as part of a less-than-truckload business. In contrast the bulk haulers of hazardous materials in tanks are about one-third the size of the average hazardous materials firm. Tank truck firms rarely transport general freight and many of them are private rather than for-hire common carriers.

Hazardous Commodity Hauled. This subsection reports on the percentage effects of hauling different types of hazardous cargoes on accident, and fatality and injury, rates. The effects are derived from the multiple regressions. As such they represent the effects of carrying a specific hazardous material category over and above the effects of the firm characteristics reported above. For example, the effect on accidents of carrying liquids in tanks makes allowance for the fact that tank truck carriers are relatively small and that small firms tend to have higher accident rates.

The percentage effects on accident rates, derived from the coefficients in the multiple regressions, are shown in table 3. The most obvious conclusion that can be drawn from the table is that carriage of some types of hazardous materials is characterized by accident, and fatality and injury, rates that are significantly different from the average. The flat $300 fee will prove to be an ineffective device for ensuring that hazardous materials shipments that pose the highest risk to society bear the highest proportion of the costs of emergency response.

As to the specific hazardous commodities, we note that carriers of gases in packages, and liquids in tanks, appear to pose the greatest threat. They have a rate of accidents, and fatalities and injuries, that is 10% higher than that of carriers who do not haul these commodities.

Carriers of gases in tanks have a rate of fatalities and injuries that is no different from that of carriers that do not haul this commodity group. However, the rate of reportable accidents is 15% less. The difference in the two percentages suggests that the carriers of these products tend to have accidents that involve high rates of personal injury and death.

Carriers of radioactive materials appear to have a high reportable accident rate, one that is 23% above that of firms that do not carry commodities in this group. However, it is likely that this finding is due to scrupulous recordkeeping by this type of carrier, because their rate of fatalities and injuries is not significantly different from that of other carriers.

Carriers of hazardous wastes have significantly lower accident, and fatality and injury, rates than carriers who do not haul this commodity.

Severity of Accidents for Different Hazardous Materials

The analysis in the preceding section only gives an indication of the frequency with which accidents occur, and some indication of the severity of the accidents. However, measures of fatalities and injuries do not give a full representation of the

Table 2: Comparison of Firms Hauling Various Hazardous Cargoes (in descending order of fleet mileage)

Commodity	% Long Distance	% General Freight	% Private	Fleet Miles
Radioactive	64	54	30	22,100,000
Explosives	62	44	50	10,100,000
Poisons	63	45	43	8,600,000
Hazardous Wastes	75	13	52	5,100,000
Other Hazardous Commodities	64	35	55	4,100,000
Gases in Packages	54	27	70	3,900,000
Liquids in Packages	63	34	57	2,700,000
Gases in Tanks	51	5	75	1,400,000
Liquids in Tanks	54	5	73	1,100,000
Average	60	27	61	3,600,000

Table 3: Effect on Accident Rates of Hauling Specific Hazardous Commodities (in descending order of effect on fatalities and injuries)

	Predicted Percent Effect on	
	Reportable Accidents	Fatalities & Injuries[1]
Gases in Packages	+12.2%*	+10.4%*
Liquids in Tanks	+ 7.4%*	+ 9.0%*
Radioactive	+22.8%*	+ 3.4%
Explosives	+ 1.5%	+ 1.1%
Poisons	+ 2.5%	- 0.2%
Liquids in Packages	- 1.9%	- 1.5%
Gases in Tanks	-15.5%*	- 3.7%
Hazardous Wastes	-12.5%*	-16.3%*

Notes

* Indicates statistically significant, from firms who do not carry this commodity, at the 5% level.

[1] For audits conducted prior to November 1, 1990.

type of emergency response that may be needed for different types of hazardous materials. Reference to the United States government's *Emergency Response Guidebook* or the Canadian government's *Dangerous Goods Initial Emergency Response Guide* provides more information on the specialized protective clothing and extinguishing agents that must be used for different types of hazardous materials, and on the area around an incident that must be evacuated. Clearly information of this type should be combined with our findings on accident frequency when setting license fees.

3. A PROPOSED ALTERNATIVE SYSTEM OF FEES

In setting its license fee DOT selected certain categories of hazardous materials and levied a flat $300 annual fee on the carriers of these materials. Some people may argue that the setting of a flat license fee has favorable safety implications because it discriminates in favor of large trucking firms and those who specialize in the transportation of hazardous materials. We find that accident rates decline with firm size, and that firms that specialize are safer than general freight firms. If the specialized hazardous material carrier is also a private carrier then the accident record is even better. However, the fee clearly discriminates against small carriers. It also discriminates against shippers and receivers of hazardous materials who, by the nature of the size of shipments they make or their locations, cannot use large or specialized carriers. Even though the $300 fee is modest, it is a barrier to entry. Discrimination in favor of large firms can lead to oligopoly and increased shipping rates. It is possible that the increased costs of shipping may exceed the benefits from a reduced number of accidents.

More important, we argue that the flat fee system fails to take account of the actual differences in the number of accidents and severity of the accidents of the different commodity groups and the kinds of motor carriers that transport them. In this section of the paper we discuss a proposed system of fees that would better ensure that individual motor carriers internalize the full costs of accidents. By doing so society will encourage motor carriers, and possibly shippers, to make investments in safety that will bring them closer to socially optimal levels. Our discussion falls into three categories: recovery of variable costs, the structure of fees to raise revenues to provide additional and higher quality emergency response, and the disbursement of such revenues.

Recovery of Variable Costs

The first part of this paper made the point that there are certain types of costs associated with accidents that are not usually recovered from the offending party. Public agencies may bear the costs of cleaning rivers and lakes, and restoring wildlife and vegetation. The highway pavement, street furniture and utility infrastructure may need to be replaced or repaired. Police officers and other officials may have to work overtime if neighborhoods have to be evacuated. Evacuations impose considerable costs on social service agencies, and on the households and businesses involved. Fire departments incur variable costs if overtime or attendance fees have to be paid and when specialized chemicals or foams are used.

A trucking firm or other party that causes an accident should be presented with a bill that covers all of the directly measurable variable costs incurred in coping with the accident and in repairing the damage done to the environment.

Annual Fees

We hold that annual fees for trucking firms should be large enough to cover a certain proportion of the special facilities that have to be available to cope with an accident. That proportion should reflect the percentage of hazardous materials truck accidents in which the truck was at fault. These fees are necessary because a fire department that responds to hazardous materials accidents, as well as residential and commercial fires, is a different fire department than one that only has to respond to the latter. It is a department that is more expensive to equip, staff, operate, and manage. As discussed in the first section of this paper, the fire department may have to purchase more or higher grade equipment, own special protective clothing, and perhaps rely less on volunteer labor. In addition, there are recurrent annual expenses associated with sending staff to specialized training courses and conducting practice sessions.

To give the correct incentives to motor carriers, the system of fees should reflect that transporters of specific hazardous materials that have higher frequencies of accidents and/or pose greater risks when accidents occur should pay more than firms that pose lower risks or have accidents less frequently. Empirical evidence of differential accident risk and severity was presented in part two of this paper. Based on this analysis, we suggest that the fee structure should have the following features:

1. The larger the firm the larger the fee. However, the fee should increase at a declining rate. That is to say that while large firms will pay more than small firms, the implicit fee per mile will decline with firm size. All evidence suggests that accident rates decline with the annual mileage run by a firm.

2. The higher the proportion of a firm's business that is hazardous, the higher should be the fee. The only modification to this rule is that firms that specialize in hazardous materials should pay a lower fee than those that transport hazardous materials as part of a general freight business, or those that carry many hazardous materials. Unfortunately, neither the researchers nor DOT have any data with which to determine the split of hazardous to non-hazardous cargoes.

3. Firms who primarily transport hazardous materials over short distances in urban areas should pay a lower fee. Our findings are that urban accidents, while occurring relatively more frequently, are primarily minor in nature. Serious accidents occur with a higher frequency on the open road in less populated areas. In

addition rural areas are more likely to need assistance in training volunteer fire departments and providing the types of specialized equipment that they would not ordinarily need.

4. Private carriers should pay fees that are about one-third less than for-hire carriers.

5. Firms that have an unsatisfactory safety audit rating are now banned from transporting hazardous materials (Sanitary Food Transportation Act, 1990). It has been argued that the safety audit was never intended to be used as a barrier to entry, and that it is not appropriately used for that purpose (Kenworthy, 1993). We argue that it is not necessary to enforce a ban if firms bear the full costs of accidents, and firms with unsatisfactory ratings pay substantially higher annual fees. Even though we find that carriers with an unsatisfactory rating do not have a higher incidence of fatalities and injuries, they do have a 50% higher rate of accidents compared with firms rated conditional or satisfactory. Accidents that only involve property damage still require attendance by response personnel and handling of any spills.

6. The fee should reflect the accident risk of the specific hazardous material(s) carried. In setting this schedule of fees one should consider frequency of occurrence information, such as that contained in table 3, and knowledge of specialized equipment and training that is necessary for particular commodities. On the basis of the analysis in this paper, carriers of bulk liquids in tanks and gases in packages should be paying high fees while carriers of hazardous wastes should have relatively low fees.

We recommend that the fee be based on the following information collected from applicants: annual firm mileage (or other surrogate such as number of power units); approximate proportion of the firm's ton-miles in each of several broadly defined hazardous commodity groups; private carrier status; and proportion of drivers on long-distance trips. With the exception of the information on the proportion of ton-miles, this information is already collected as part of the census data held on all known carriers by DOT.

Econometric analysis of accident data, such as that reported in this paper, would then allow DOT to produce a simple multiplicative equation by which it could determine the appropriate fee to be paid. For example, the fee equation might be something like:

Base fee
x 0.96 x log of annual mileage
x 0.7 if a private carrier
x 1.5 if greater than 50% of drivers are on long-distance trips
x 1.5 if an unsatisfactory audit rating
x 1.1 x proportion of ton-miles that are hazardous liquids in tanks
and so on.

Calculation of the fee could then be made by computer in a similar fashion to the well known and accepted way that insurance agents calculate automobile premiums. If this system appears to be too complex for practical implementation, we recommend that a coarser schedule be derived based on bands of firm size, principal hazardous commodities carried and private carrier status, and presented in matrix form.

Disbursement of Funds

The primary purpose of this paper is to make suggestions about a system of fees and charges for accidents that would be an improvement over the flat fee DOT has adopted. However, a brief discussion of revenue needs and disbursement policies is in order. We focus on the annual fee in the discussion of revenue because the charging of variable costs will obviously be related to the amount of harm caused in individual accidents.

HMTUSA permits DOT to make grants to local response agencies to fund training and planning for hazardous materials accidents. HMTUSA does not have any provision for using license fees to provide funding to local authorities to purchase specialized equipment. This is a serious deficiency. There is a conscious effort being made by transportation risk management professionals and politicians to route hazardous materials away from populous areas. The lightly populated counties and small towns in the vicinity of these alternative routes do not normally have the amount and kinds of specialized, expensive equipment needed to deal with an accident. In addition, these areas do not receive any of the direct benefits, such as employment or tax revenues, of hazardous materials production and the use of such materials as intermediate goods. These communities should also receive funds to pay for additional and more expensive equipment needed to respond to accidents.

Not all of these monies should be raised from the trucking industry. The truck is at fault in only a proportion of road accidents involving hazardous materials. Other at-fault parties such as motorists and pedestrians should bear a proportionate share of the financial burden. This could be achieved by a contribution from general tax revenues, or a requirement that states match grants from the federal government out of a surcharge on automobile registration fees or a tax on insurance premiums.

It is beyond the scope of this paper to discuss the total annual revenues that need to be collected. Clearly there is some economically optimal provision of first response. DOT will obviously need to have some standards which it will use in approving disbursement to individual local agencies. Criteria will include the volume of hazardous materials in the locality, the nature of any specific material that is predominantly shipped in the area, the current equipment and staffing of the fire department, and the availability of such equipment and expertise by neighboring departments. In the event that certain routes become designated as hazardous materials corridors, standards may have to be developed as to the type of first response that should be available and the distance between qualified first responders.

CONCLUDING REMARKS

Economists argue that firms will make the socially correct decisions on prevention of accidents when they must bear the full costs of incidents that they cause. Currently some of the costs of environmental cleanup are borne by the public, as are all the costs of emergency response provision. The $300 annual fee for transporting certain types of hazardous materials that is being implemented by DOT is clearly a step in the right direction. However, we believe that an improved system of fees can be devised that would produce even greater benefits. Annual fees should reflect the expected costs of emergency response efforts. We have determined that these costs are related to the types of hazardous materials being hauled and the types of carriers that haul them. Such a system would more faithfully reflect the mandate given to DOT by the enabling legislation (HMTUSA). In addition, public agencies should be aggressive in billing motor carriers or other at-fault parties for all identifiable costs incurred in dealing with an accident. These costs include environmental restoration, extinguishing agents used, repair of highway facilities, and the costs of evacuating neighborhoods in the vicinity of accidents.

ACKNOWLEDGEMENT

This work has been financially supported by the U.S. Department of Transportation through its University Transportation Centers program at the Great Lakes Center for Truck Transportation Research, University of Michigan, Ann Arbor. We would like to thank our research assistants Yojai "M" Yod-in and Mona Shah. We also wish to express our appreciation to the Federal Highway Administration for providing the data.

APPENDIX: THE POISSON TECHNIQUE AND VARIABLES EMPLOYED

Analytical Method

In our empirical analyses we adopt a type of regression technique based on the Poisson distribution in preference to the more common, ordinary least squares (OLS) approach. Professional opinion suggests that the Poisson distribution is more appropriate when dealing with discrete count data (Cameron and Trivedi, 1986; Hausman, Hall and Griliches, 1984). In the Poisson formulation the number of accidents is the dependent variable; the explanatory variables are multiplicative; and one takes the exponent of a coefficient in order to interpret it. Exposure to accidents, interpreted as truck miles in our study, is one of the explanatory variables. This contrasts with OLS style regressions which typically have accident rates (accidents per mile) as the dependent variable. The Poisson regression is by definition non-linear and fits an exponential curve to data.

As measures of goodness of fit, the percentage of variation in the dependent variable explained by the regression and the log-likelihood statistic are typically presented. The latter statistic is usually compared to the log-likelihood of a regression with only a constant. However, because accidents are heavily related to exposure we felt that the correct base would be a regression with a constant and the log of fleet miles.

Variables Employed

The Accident Experience of the Firm in the Previous 365 Days. Accident data are notoriously unreliable in the trucking industry. The widely used national truck accident database of the DOT's Office of Motor Carriers is flawed because accidents are self-reported. It is generally believed that there are serious inconsistencies and under-reporting of damage-only accidents. Our data come from questions asked directly of managers by inspectors, and therefore should be more reliable. Two measures of accidents are used. The first is called "reportable accidents." Reportable accidents are defined as accidents involving a fatality, an injury, or more than approximately $5,000 in property damage. We also use the total fatalities and injuries measure in our analyses, but must then limit ourselves to the audits conducted prior to November 1, 1990 because DOT ceased to collect these data after this date.

The Log of Total Fleet Miles of the Firm in the Past Year. We use these data to capture both the amount of exposure to accidents and any firm size effects on accident rates. Testing of the coefficient against 1 determines whether accidents increase more or less than proportionately with miles. Inclusion of this variable allows us to colloquially refer to "accident rates" when interpreting the coefficients on other explanatory variables.

The Percent of Drivers Employed on Trips over 100 Miles. We hypothesized that firms whose primary work involves short distances, typically in urban areas, have a different accident experience from firms whose operations primarily involve long-distance service, either on the interstate highway system or rural highways. Urban firms may be involved in a higher number of accidents, but many of these involve minor amounts of property damage which are not included in the federal definition of a reportable accident. This variable cannot be expressed in logarithms because several firms report zero long-distance drivers.

Private Carrier Status. We use a dummy (0-1) variable to indicate if the firm is a private carrier rather than a for-hire carrier.

The Type of Goods Hauled. The nine categories of hazardous materials that were used in the analysis are shown below, with the aggregations that were necessary to avoid collinearity problems being shown in parentheses.

- Explosives (combination of categories explosives A, explosives B, explosives C, and blasting agents)
- Liquids in tanks (flammable liquids, corrosives, oxidizers and combustible liquids)
- Liquids in packages (flammable liquids, corrosives, oxidizers and combustible liquids)
- Gases in tanks (flammable gas, non-flammable gas)
- Gases in packages (flammable gas, non-flammable gas)
- Poisons (poison A, poison B)
- Radioactive materials
- Hazardous wastes
- Other hazardous commodities (flammable solid, organic peroxide, irritating material, "other regulated materials," etiologic agent, "hazardous substances," and cryogenics)

Performance on the Federal Safety Audit. Federal and state inspectors visit the operating bases of carriers and make assessments of their compliance with federal safety regulations and safety management policies with regard to maintenance, and driver hiring and training. The inspectors examine records and interview management officials, but do not actually inspect any equipment or test drivers. The inspectors have a standard list of 75 questions. They mark a pass or fail on each question, but can also append comments and supporting documentation. The carrier is then rated as satisfactory, conditional or unsatisfactory based on the answers to the questions, and a weighting scheme that is not known to the public. Firms that appear to have questionable safety practices, but have not actually violated federal regulations, are typically rated conditional pending further investigation. For the purposes of this paper, we represent the audits by a dummy variable to indicate firms that are rated unsatisfactory. Summary statistics indicate that satisfactory and conditional firms have broadly similar accident rates, while those for unsatisfactory firms are much worse.

REFERENCES

Cameron, A. C., and P. Trivedi. 1986. "Econometric Models of Count Data: Comparisons and Applications of Some Estimators and Tests." *Journal of Applied Econometrics* 1:29-54.

Hausman, J., B. H. Hall and Z. Griliches. 1984. "Econometric Models for Count Data with an Application to the Patents-R&D Relationship." *Econometrica* 52:909-938.

Kenworthy, W. E. 1993. "Compliance and Enforcement Problems in Hazardous Materials Transportation: Will the Hazardous Materials Transportation Uniform Safety Act of 1990 make a Difference." In L. N. Moses, ed, *Transportation of Hazardous Materials: Issues in Law, Social Science and Engineering*. Boston: Kluwer Academic Publishers.

Moses, L. N., and I. Savage. 1992. "Characteristics of Motor Carriers of Hazardous Materials." *Proceedings of the International Consensus Conference on the Risks of the Transport of Dangerous Goods*. Institute for Risk Research, University of Waterloo, Ontario, Canada.

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COSTING THE MOVEMENT OF HAZARDOUS MATERIALS BY RAIL

Michael W. Tretheway and W.G.Waters II[1]

1. INTRODUCTION

Determining the costs of hazardous materials (hazmat) transportation is an important component in understanding the economics of hazmats. This paper provides an overview of the steps involved in determining the costs associated with hazmat transportation by rail and in particular comments on the suitability of the Interstate Commerce Commission's Uniform Rail Costing System (URCS) for hazmats.

This paper concentrates on the transportation costs of hazmats, i.e., the "private costs" in contrast to social costs such as the risks of accidents and consequent external costs borne by society generally. Other papers in this volume address the latter concerns. The private costs of transporting hazmats are, of course, a part of the total social costs associated with these commodities. It is important to be aware of the real resource costs associated with their transportation, especially in considering alternate regulations of rail operating procedures for hazmats which will affect transportation costs.

This paper begins by addressing the general problem of railroad costing, a problem shared in varying degrees by other transport modes and industries. Transportation firms are multiproduct enterprises. They incur a variety of costs in supplying a wide array of services. Because it is economical to provide services in common rather than serve each commodity one at a time, there are major difficulties in identifying exactly which costs are attributable to individual traffic carried. Railroads (and other industries) have devised various procedures to help identify the costs associated with different services provided.

The basic approach to rail costing is outlined in section 2 below. Railway cost estimates are developed by, first, identifying the costs associated with various intermediate activities. Then, the costs of specific traffic are estimated by identifying the amounts of various intermediate activities required to transport the goods from origin to destination. Different types of traffic impose different requirements on rail operations, thus causing differences in total movement costs. The ability to estimate the costs of particular movements, such as a type of hazmat for a particular route,

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1. The authors wish to thank our colleague, Garland Chow, for helpful comments on an earlier draft.

depends on the ability to link costs with intermediate rail operations, and the ability to identify the operational requirements to handle the particular movement. Section 3 describes URCS, a particular costing system adopted by the Interstate Commerce Commission (ICC) as a "general purpose costing system." Section 4 discusses the types of transportation problems that arise with hazmats and the ability of URCS or other costing systems to reflect the differences in costs associated with different types of traffic and rail operations. A conclusion summarizes the key points.

2. RAIL COST ANALYSIS

The Rail Costing Problem

As indicated at the outset, a costing problem arises in multiproduct enterprises because of the variety of costs incurred on behalf of a large number of services provided. It can be very difficult to identify portions of total costs which are attributable to specific outputs. Costing is the procedure to attempt to "unscramble the egg."

Costing is necessary for various purposes, and the purpose can influence the costing procedures employed.[2] If one is forecasting a departmental budget in a railroad, there is little need for disaggregate information about costs of different traffic types. A general forecast of aggregate traffic volumes would probably be sufficient. If one is estimating the costs of infrastructure investment or other capital expenditures in a railroad, one needs selective information from the railroad's database; detailed cost analysis of individual movements usually is not necessary. The costing problem of interest here is the need for *movement* or *traffic* costing. This is the need to estimate the variable costs associated with carrying a particular piece of traffic, i.e., the incremental costs of expanding or contracting this one movement given the rest of the operations.[3] This is the cost information needed to evaluate pricing and service decisions.

Various participants are interested in cost analysis. Rail companies need to know variable costs as a floor for price negotiations in competitive markets. Competitors would like to know something about a rival carrier's costs. Shippers desire cost information as a possible bargaining tool. Regulators, where there is regulatory jurisdiction, need a basis for making price-cost comparisons. Different groups have different interests in cost analysis, and in this world of imperfect information, their interests may occasionally influence the particular methods of cost analysis employed. We abstract from any such strategic maneuvering in cost analysis. All these parties share a common interest in being able to identify the costs incurred as a

2. For an overview of rail costing purposes and approaches, see Waters, 1985.

3. Economists distinguish between average variable costs and marginal costs. The difference is relevant when cost relationships are nonlinear. As will be seen, the URCS system uses linear equations in its present form.

result of carrying (or not carrying) a particular block of traffic.

Figure 1 illustrates the basic costing problem. A railroad employs various inputs of labour, fuel, capital equipment, materials, etc. to produce various intermediate activities. These include yard operations, dispatching, linehaul transportation, track and equipment maintenance, marketing and sales activities, general administration, etc. These various activities are combined to supply a large number of services, different types of traffic, on different routes, in different directions, at different times. The costing problem is to try to link portions of the costs recorded in the left hand side of figure 1 with one of thousands of individual outputs indicated on the right hand side of figure 1. For the most part, the left hand side of figure 1 is not the problem. Generally it is possible to identify input expenses with particular intermediate activities, although some inputs are shared among them. The problem of untraceable costs arises primarily on the right hand side of figure 1. A multiplicity of outputs is supplied with the various intermediate operations, and it is difficult and can be impossible to link portions of the costs on the left hand side with individual outputs on the right hand side.

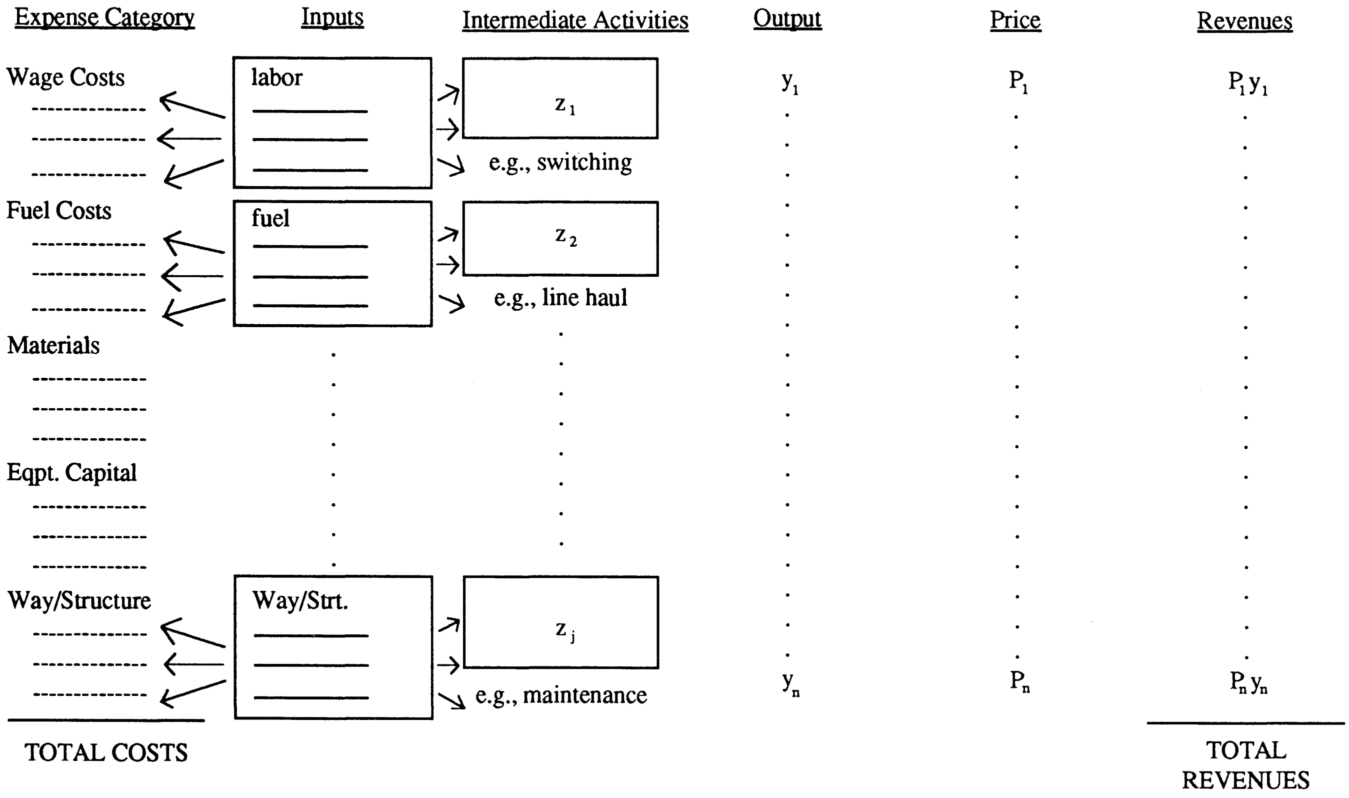
The Costing Process

Rail costing is, broadly, a two-stage process.[4] The "cost development" phase focuses on the various intermediate activities of the railroad and attempts to determine the costs associated with supplying these various activities. Individual expense accounts are examined to determine how they relate to rail operations. Accounts might be assigned directly to some activities, or often regression analysis is used to identify empirically the link between certain expense categories and measures of intermediate rail activity. For example, freight car maintenance expenses might be linked to the number of freight-car miles. Fuel expenses might be explained in terms of train-miles or gross ton-miles. Different cost accounts explained by the same intermediate activity variable can be grouped together. Note however, that there may be some cost categories that are difficult to relate even to intermediate activities of a railroad. Some costs may be shared by several intermediate activities and cost assignability might prove elusive. There are "constant costs" in rail activities, costs that cannot be identified with particular operational activities nor with final outputs, yet they are costs that are escapable if operations were to cease. These are costs that must be covered from all rail traffic taken together, rather than be assigned to individual traffic movements. This first phase includes identifying average operating performance variables, e.g., time required to switch cars, average load per car, average train size, etc.

The second phase in costing is to use the cost estimates associated with the intermediate activities to develop an estimate of costs associated with servicing a particular traffic movement. The procedure is to identify the various intermediate activity

4. For a further introduction to rail costing, see Hariton, 1984.

Figure 1. Illustration of Difficulty of Linking Expenditures with Final Output in Rail Transportation



levels needed to serve a particular commodity movement, and the sum of the costs of these intermediate activities is the estimate of costs for the traffic movement. A carload shipment from Omaha to Chicago requires: (1) some administrative expenses associated with recording and billing the movement; (2) use of a car, which entails opportunity costs as well as maintenance of the car; (3) that the car be switched at the origin and destination, and possibly at interchanges en route; and (4) fuel for hauling the car, as well as a proportionate share of the expenses of running and maintaining the locomotives. The estimated costs of handling some specific traffic is the sum of the costs of all the intermediate activities that are required by that traffic, plus any additional expenses uniquely attributable to that traffic (e.g., special handling, pickup and delivery, etc.). This is an estimate of the variable (marginal) costs associated with that particular traffic, holding other traffic and operations constant.

The incremental costs of a particular movement are influenced by the time horizon involved. The incremental costs of one more car on an underutilized train about to depart are different from an ongoing commitment to add a car on a permanent basis. Some costing systems have flexibility to handle different time spans, but most costing systems are developed for a "longer run" period, i.e., a time period sufficient to adjust train size, equipment used, etc.

Two further comments are in order. The first is a reminder that these are cost *estimates*, they are not precise measures of costs but estimates based on imperfectly recorded data and numerous opportunities for judgement or error in analyzing particular cost relationships. But they are what we have. A textbook ideal measure of marginal costs is unattainable for a vast multiproduct enterprise with many shared and indivisible cost components. The second comment is a reminder that not all costs are assignable to individual outputs, but they are costs that must still be covered. Optimal pricing for multiproduct enterprises with shared costs must include markups above identifiable or traceable marginal costs (and optimal markups will differ across commodities).

Economists and Practitioner Cost Functions

The costing approach just described is quite different from the type of cost functions and cost analysis usually carried out by economists. It may be instructive to contrast briefly the differences in the usual economist's approach with what is embodied in rail costing procedures, which we label "practitioner" cost functions (Waters and Tretheway, 1989).

Most economics textbook discussions, as well as empirical estimation of cost functions by economists, focus on aggregate cost functions. The total costs of a firm are what is being explained rather than some component of the firm's costs. A multiproduct cost function would be written:

$$C = C(\{y_i\}, \{w_k\}, T)$$

where C is total costs, y_i is output i; w_k are prices of inputs, and T is a technology variable. Essentially, economists abstract from the details of the production process, i.e., a "black box" approach. This is illustrated in figure 2. Aggregate cost functions in transportation involve high aggregation. Most econometric cost functions lump all freight activity together, i.e., all ton-miles are treated as homogeneous. In practice, most such cost functions only distinguish freight from passenger miles, although many also incorporate average length of haul and average load as characteristics of output.[5] Very few econometric cost functions have been able to incorporate more than a few freight categories.

The high aggregation in economists' cost functions is not necessarily a handicap. Economists generally are interested only in broad characteristics of production and costs, such as whether or not there are economies of density and/or scale in total operations. For these questions, it may not be necessary to have a high degree of specificity for individual output categories.

In contrast, practitioners have little interest in economists' cost functions precisely because of their high aggregation. A high priority in practitioners' cost analysis is the ability to distinguish the costs associated with different outputs. They accomplish this indirectly by disaggregating costs and estimating them in terms of the intermediate activities in the rail production process. Unlike the economists' treatment of production as a "black box," the practitioner approach is to identify explicitly the intermediate activities in the production process. The costing system is oriented to these activities rather than final outputs. This is illustrated in figure 3. Unlike figure 2, rather than attempt to directly link costs with final outputs, practitioners estimate a series of disaggregate cost functions for various intermediate activities. Arguably, there is much less heterogeneity in the various categories in the practitioner approach. Switching miles are relatively homogeneous, and they are distinct from linehaul locomotive miles. Similarly, freight car miles and track maintenance activities are distinct activities in rail operations. Practitioners would argue that specifying costs in terms of these activities is much more reliable than estimating costs directly as a function of highly heterogeneous total freight ton-miles (aggregate output).

A shortcoming of the practitioner approach is that it treats each component of total costs as separable from the rest. The costs of running trains are treated as independent of the expenditures on track maintenance; freight car maintenance is regarded as independent of track maintenance. In general, the disaggregate practitioner approach imposes various separability assumptions on the production process. This approach overlooks possible substitutions and/or complementarities among various components of rail operations. The aggregate econometric approach does not impose these restrictions.[6]

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5. For a review of the development of econometric studies of rail costs, see Keeler (1983) and Waters and Woodland (1984). Some more recent contributions include Caves et al. (1985); Braeutigam, Daughety and Turnquist (1982); and Daughety, Turnquist and Griesbach, (1983).

6. The practitioner cost functions generally omit input prices, therefore their equations may suffer from an omitted variable bias.

Figure 2

Illustration of Economists' "Black Box" Treatment of Production in Estimating Cost Functions

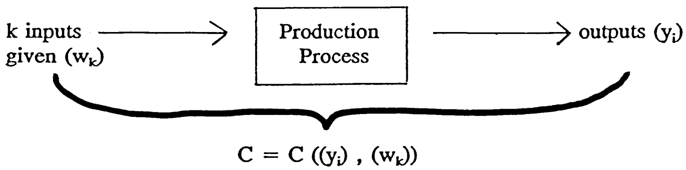
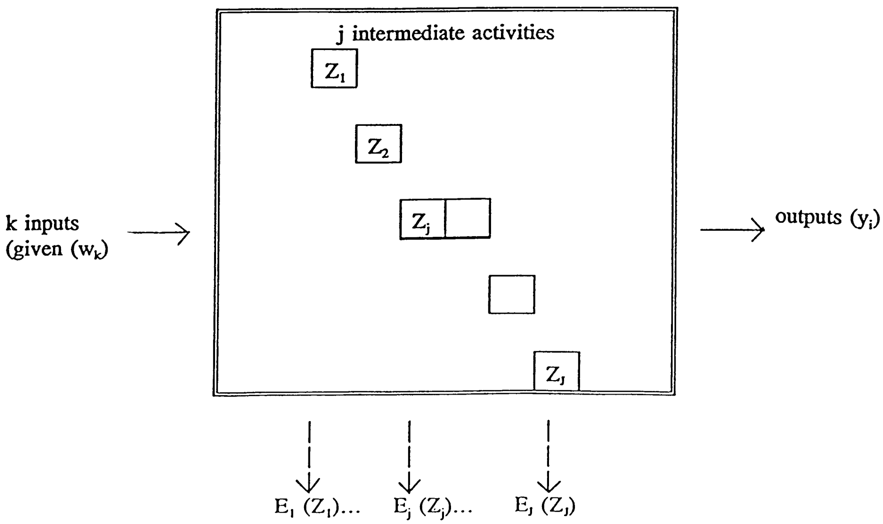


Figure 3

Illustration of Practitioner Disaggregate Approach to Production and Cost Functions



The econometric and practitioner approaches to statistical cost analysis have evolved more or less independently, with very little overlap. Each approach serves a quite different purpose, and each finds fault with the other approach.[7] The economists' specification of cost functions embodies extremely high aggregation but it encompasses the full production process including any complementarities or substitution possibilities among inputs and intermediate processes. The practitioner approach has greater specificity in its disaggregate cost equations but (implicitly) imposes separability restrictions on these cost functions. We ignore these methodological issues in the subsequent discussion.

2. THE UNIFORM RAIL COSTING SYSTEM (URCS)

The significance of URCS is that it is a "general purpose costing system" approved by the ICC for regulatory purposes (ICC, 1989). URCS has been under development for several years.[8] It replaces Rail Form A, a costing procedure developed in the 1940s and used with modification until recently.

There are alternate costing systems. All railroads have extensive information and costing systems, but they are proprietary. URCS is a readily available costing system. There are commercial vendors of costing systems which replicate URCS (or similar costing frameworks) and allow users to modify the system.[9] Hence URCS is the costing system readily accessible to shippers and it is the initial basis for cost analysis to be used by the ICC where it has regulatory jurisdiction.[10]

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7. Critiques of what we call the "practitioner approach" would be primarily studies focused on ICC costing procedures. Earlier criticisms of ICC costing methods would include Meyer et al. (1959); Friedlaender (1969); Meyer and Kraft (1971); and Griliches (1972). Economists' criticisms of the approach underlying URCS include Braeutigam and Swanson (1980), Friedlaender and Spady (1980), and McBride (1982) and Griliches (1988).

8. A concise review of the development of URCS is Johnson and Yevich (1982). The main reports are Interstate Commerce Commission (1981 and 1982). The version of URCS adopted followed the work of Wesbrook (1988) and testimony in connection with ICC Ex Parte 431 (Sub-No. 1).

9. For example, DNS Associates' MicroURCS (1984). There are numerous other commercially available rail costing programs available, as well as rail costing services provided by many consulting firms, which provide much more detailed cost analysis than the standard URCS framework.

10. ICC regulatory jurisdiction over rate reasonableness is not a simple rule. The railroad must be "market dominant" and the jurisdictional threshold for rate regulation is a rate in excess of 180% of variable costs. This is not a hard and fast rule; the "revenue adequacy" of the railroad is also a consideration. Subject to this, URCS is the approved costing system for initial analysis. But note that in specific rate cases, parties are allowed to bring forth additional cost evidence, i.e., they are not limited to URCS.

URCS is developed along the lines outlined earlier. Regression analysis is carried out for sixteen cost account categories regressed on "output" (activity levels) thought to be appropriate for the cost category, along with a size or capacity variable to control for this influence on costs in different firms. The database is a combined cross-section and time series data, for 21 firms and eight years of data from 1978 to 1985. Firm and time dummies are included in the regression analysis and modern econometric methods are used to estimate the practitioner-type activity cost functions (Wesbrook, 1988).[11] At present, regressions are limited to linear equations. Further refinement of URCS cost equations will emerge as the Ex Parte 431 Sub-no. 2 proceeding continues.

The basic structure of URCS is outlined in figure 4. The details of the various steps and work tables are not critical for this paper. It is sufficient to recognize the general procedure involved in developing URCS, and we can concentrate on its applicability to costing hazmat movements. The regression analysis is used to determine the variability of cost categories with measures of intermediate activity levels (they refer to variables such as car miles and train miles as "output" variables, but they are more accurately thought of as intermediate outputs). Some cost accounts are declared to be 100% variable, and for these an average variable cost is calculated for each railroad. About 20% of total costs are excluded from the regression analysis and variability is assigned directly. For example, car ownership costs are dealt with directly rather than by regression equations. For the remaining 80% of total cost categories, linear regression analysis is used to determine how costs vary with "output." A series of worktables (not detailed in figure 4) develop unit costs (costs expressed per unit of various intermediate activity measures) for the individual railroads (worktable E). The regression analysis is carried out across the railroads, i.e., the cost experience of railroads is pooled to estimate cost/activity relationships. However, there are separate intercepts in the regression for each carrier, to recognize the unique operating environment and other cost characteristics of a particular carrier. In the regression, one must assume activity units are homogeneous across railroads, although total cost levels differ among railroads due to size differences and firm- and year-specific (dummy) variables. The regressions are used to calculate the variability of costs with activity levels for each railroad. The variability differs across the railroads, hence their respective unit costs differ.

Phase III or worktable F is the actual costing program. As outlined earlier, a specific commodity movement is costed by identifying the various intermediate activities required and movement characteristics including distance traveled, travel time, car type required, and the probability of empty return (if backhaul traffic is not available, then the costs of returning the empty car must be included).

For the most part, the costing program is generic. That is, it does not really matter what the commodity is, except to identify the car type being used. The portion of locomotive fuel and crew costs will be a function of the weight and distance traveled and the particular railroad and route (e.g., higher costs for some railroads and

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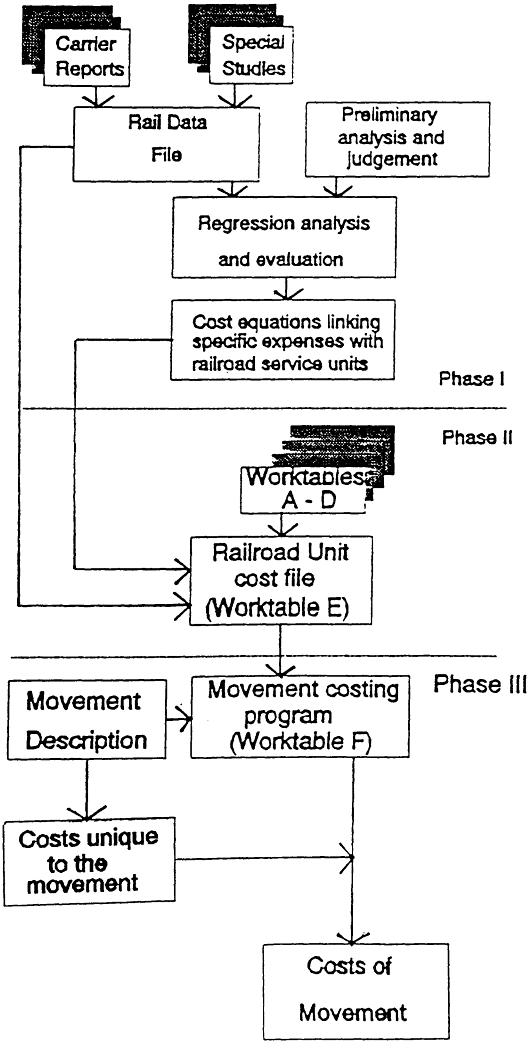
11. Adjustments are made for heteroscedasticity and autocorrelation, in addition to the fixed effects estimation employing firm and time dummies.

Figure 4

Illustration of the Uniform Railroad Costing System (URCS)



Adapted From ICC Flow Chart

routes, such as mountain regions). Most of the cost categories are treated as homogeneous with respect to the activity measure used to assign costs to the particular movement. The exception to this generic treatment is "loss and damage" costs. URCS has a file of 66 commodity classifications that contain historical records on loss and damage experience. These records are used to estimate the expected loss and damage costs assigned to the movement being costed.

The first approach is to add separately any special costs associated with the movement. All costing systems have provisions for inserting costs uniquely attributable to a particular movement. For example, if some type of special handling is required, this cost item is added to the costs estimated via the standard costing program. This is shown in the box for "specific costs unique to the movement" near the bottom of figure 4. There are three ways to modify the URCS cost estimates for particular commodity/movement characteristics, such as would be associated with hazmats. Second, it is possible for a user to intervene in the URCS cost calculation to replace the "default values" with a cost estimate thought to be more relevant to the particular movement (in the movement costing program in figure 4). Of course, this requires that the analyst have the knowledge and figures with which to intervene.

4. IMPLICATIONS OF HAZMATS FOR RAIL OPERATIONS AND COSTS

Hazmats include a great variety of commodities and substances. There are different reasons why they are considered hazardous. Their shared characteristic is that they are not treated like other commodities. Rail costing systems, especially general purpose systems such as URCS, are based on data from actual rail operations and costs. In the case of URCS, the cost relationships are developed by pooling system average data for several railroads and years. That is, the resulting estimated cost relationships are based on the average experience of railroads. The cost estimates are expected to be reliable providing the underlying rail operations and traffic types are unchanged. For atypical traffic types, cost estimates need to be adjusted to reflect the different impact on costs associated with traffic that requires special treatment. Hazmats are such traffic.

Different hazmats may bring different transportation requirements with correspondingly different cost implications. The discussion here is limited to general characteristics associated with hazmat transportation that do not necessarily apply to all hazmats.

Hazmats can affect rail operations, and thus costs, in many ways. First, hazmats may bring particular and identifiable additional expenses such as special handling. For the most part, these costs can be directly identified and assigned to the specific hazmat movement. But hazmats can affect the railroad's costs indirectly, and these costs are not always easily identified. One is a possible effect on the underlying cost coefficients and/or operating parameters in the costing program. Insofar as hazmats result in higher cost operations, and a number of hazmats are currently being carried, then the total and average costs of rail operations are affected by hazmats. The unit cost coefficients in costing programs are developed from existing rail operations. That is, the presence of hazmats increase the calculated average costs for all traffic. Unit costs for nonhazmats would be overstated. We suspect that this is not a serious problem. Total movements of hazmats are about 5% of total rail movements (based on figures cited in Wolfe, 1984, p. 5). Hence we doubt that this is an important factor for most railroad average cost data.

Hazmats may also affect rail costs indirectly. They can put constraints on rail operations and thereby increase costs on other traffic. For example, suppose a circuitous routing is necessary to avoid exposing populated areas to a hazmat. The increased costs of distance and time can be identified and costed for the hazmat movement. But if the hazmat train is carrying other traffic, then a hazmat routing increases the mileage and transit time for other commodities on the train. These additional costs for other commodities are a cost attributable to hazmats, but a costing system will not identify these automatically. Efficient pricing of hazmat traffic requires that the true system incremental costs of the traffic be known. Excluding system-impact costs can result in underpricing hazmat services, and thus encourage more use of these services than would be socially optimal.

Rail costs may also be increased if investment is required in right-of-way and track in order to more safely accommodate hazmat traffic. This has an ambiguous effect on costs. The additional investment constitutes a cost increase directly attributable to hazmat traffic, but the rerouting and higher quality road may reduce operating costs for all traffic.

In general, some costs of hazmats can be identified and readily incorporated into a rail costing program. The key requirement is the ability to anticipate the implications of hazmats for rail operations, and, in turn, their implications for rail costs.

Many hazmats bring special packaging requirements, e.g., extra-strong containers to withstand collision damage (such as radioactive materials). For the most part, these costs are borne by the shipper. But they may have implications for railroads. Do special containers require special rail equipment? Does packaging affect the potential load per car and hence affect productivity of rail cars? Where special rail car equipment is required, the costs might be borne by the shipper. But even here, there are additional implications for a railway. A railroad has less flexibility with dedicated shipper-owned equipment than with railway-controlled fleets. Shipper-owned cars normally are returned empty and directly, whereas rail-owned equipment can be interchanged among different routes and traffic types, thereby enhancing productivity. Rail cars or containers may require cleaning after use, and this may require special cleaning, storage and disposal facilities. There are costs for such facilities plus the time loss while cars are handled and cleaned.

Special handling may be necessary for hazmats. Typically, these costs are known and can be incorporated into the cost estimates. Note that if special handling is a source of delay for other traffic or train operations, then the hazmats are imposing system costs on other traffic that need to be taken into account.

Hazmats could require extra yard handling (switching). If there are restrictions on where hazmats can be located on a train (e.g., to minimize chances of derailment), or what commodities can be in adjacent cars, these may impose additional yard switching activities and cost. In principle, this is a cost which can be identified. Note that there is the possibility of imposing delays on other traffic.

Hazmats can have effects on train routing and operations. An obvious example is a special routing requirement such as circuitous routing to minimize exposure to populated and/or environmentally-sensitive areas. For cost variables that are tied to distance traveled, these cost components reflect this additional cost of hazmats. However, circuitous routing also takes more time, and uses more of available track capacity. Some costs are a function of distance and time (e.g., wear and tear on rail cars is a function of use and distance, but ownership costs are a function of time). It is important that both dimensions be included in a cost analysis. If other traffic is delayed and its distance increased because it accompanies a hazmat train, then these additional costs should be attributed to the hazmats.[12] Restrictions on train speed and/or time-of-day restrictions are further examples of hazmats affecting rail operations and the costs of other traffic sharing the system.

Hazmats may lead to relocation of major facilities such as yards. There have been many pressures to relocate rail yard operations away from urban centers to less populated areas. The capital costs can be very large; operating costs could be affected positively or negatively.[13] Hazmats are not the only reason for urban pressures to relocate rail facilities away from downtown areas. Noise is an externality arising from yard operations generally, not associated only with hazmats. There are other economic pressures as well, specifically the possibility of converting rail industrial lands in urban areas to more valuable commercial and residential use. The problems assigning costs between hazmats and other traffic are obvious.

All hazmats require extra documentation, placarding and monitoring. In principle these costs are identifiable, but note that information systems and monitoring are at least partly routine overhead and administrative items. It can be difficult to allocate such activities to individual traffic. It may be necessary for railroads to have in place contingency plans and material stockpiles in the event of accidents or spills. These are identifiable costs with hazmats although it might not always be apparent how such costs should be shared among different types of hazmats.

Finally, there are the costs associated with hazmat accidents. In spite of best efforts and significantly improved safety records, rail accidents do happen. Normally, the costs associated with accidents (such as rebuilding rail lines) are absorbed into regular cost accounts. However, accidents involving hazmat traffic can have significantly higher costs, including costs of cleanup and reconstruction, opportunity costs of the rail line being out of service for longer periods of time than would be the

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12. Railroads have an option of separating other cargo from hazmats and sending the former by a more direct route. But often it is less costly to leave the train intact even though some traffic is carried greater distances than necessary.

13. An example of cost analysis of rail facility relocation for hazmats ("dangerous goods" in Canada) is Irwin and Sims (1989).

case for a non-hazmat accident, and liability costs not covered by insurance.[14]

It is evident that hazmats can have an impact on rail costs, both directly and indirectly. Because costing systems typically are developed for "average" traffic, it is necessary to modify cost estimates to reflect the extra demands placed on the rail system by hazmats. These differ among types of hazmats. It is also important to recognize that operational restrictions or complications caused by hazmats may cause delays and other costs to other traffic. Efficiency (as well as equity) requires that such costs be identified and attributed to hazmats to ensure accurate costing of hazmat movements. Most costing studies, including URCS, must be modified to incorporate these complications.

What steps are necessary to modify URCS (or similar costing models)? It is difficult to generalize because of the diversity of hazmat characteristics and regulations. The impact of hazmats on rail operations and costs will vary for different types of hazmats, and may vary with the origin-destination pair, routing, etc. There is only one general guideline: the necessity to think through all phases of a hazmat movement and identify how the hazmat movement differs from "average" traffic movements. This is the prerequisite for identifying the differential costs associated with hazmats. The next step is the cost estimates themselves. Generally these are not built-in to costing models so separate cost estimates must be made. Cost estimates might have to be "rough and ready" and hence contentious, especially the costs of system effects, e.g., the costs of delays to rail systems generally. But rough estimates of costs are better than none. Whether done by carriers, shippers or regulators, if such cost estimates are not prepared, then one is not thinking about the full costs of hazmat transportation.

5. CONCLUSIONS

The object of this paper was to address the implications of hazmats on rail costs. This is an important component--but only one--in understanding the economics of hazmat transportation. In order to understand the linkage between hazmats, rail operations and rail costs, it was necessary to outline the basic approach to rail costing systems. The ICC's URCS is a readily available costing system, acceptable for regulatory disputes but useful beyond that. Hence it warrants particular attention. URCS is an empirically-based costing system. It is based on combined cross-section and time series regressions for U.S. Class I railroads, supplemented by cost allocations for some rail accounts. URCS is a costing system to estimate the variable costs associated with specific traffic. It is based on average operating experiences of the rail industry, but also reflects differences in cost conditions among railroads.

Hazmats are not "average" traffic; they impose special documentation and

14. Hazmat accidents can result in significantly higher insurance premiums, again raising the question of how to attribute incremental costs to hazmat traffic. But also note the danger of double-counting of insurance premiums with accident costs.

operating constraints on rail operations, hence they incur costs different from the average. The availability of a costing system such as URCS provides a foundation for developing estimates of the costs of rail transportation of hazmats. But it is necessary to identify the additional demands placed on a rail system by specific hazmat movements. They can impose additional system costs due to requirements for circuitous movements, etc. The URCS costing system is adaptable to handle some special costs associated with hazmat traffic. It is possible to replace operating parameters (rail performance coefficients). There are the estimates of time or unit production of intermediate activities, e.g., time required to switch cars, load per car, train size, etc. Normally, these are based on the average operating experiences of the railroad. Of course, if one is intervening and changing coefficients in the costing program, it is crucial that realistic figures be used. For example, URCS "default values" can be replaced to reflect special costs associated with specialized equipment and handling costs.

However, there are limitations of URCS and similar costing systems for hazmat costing. The averaging of hazmat with other traffic raises estimation issues for the underlying URCS equations, although the magnitude of this problem is likely to be small as long as hazmat traffic is a small proportion of total traffic. Another potential concern is possible nonlinearities in rail costs. URCS, and most rail costing systems, rely on linear equations. Linear extrapolations of costs with output may be reasonable approximations much of the time, but they become inaccurate if nonlinearities arise, such as operations in congested conditions. Externality problems are often characterized as having costs that rise disproportionately with total output. The importance of this problem is uncertain. More serious is the attribution of system cost impacts, such as requiring all traffic for a train to be routed circuitously. URCS is not able to identify and adjust for such cost effects at present. The high degree of aggregation that characterizes economists' rail cost functions pose problems because of their high aggregation, but they have the advantage of implicitly incorporating system effects because costs are aggregated. Ideally, however, one needs to be explicit in incorporating system effects. This requires a costing system which is sensitive to route and traffic conditions, and interactions of traffic types on operations and hence costs. A promising approach to hazmat costing is to try to identify system impacts and use URCS (or a similar costing system) to estimate system impacts on costs such as additional car miles associated with other traffic affected by the hazmat traffic. Recognizing more general costs of system delay will be more difficult. But difficult as they may be, they are essential steps in developing accurate costs of rail hazmat traffic.

REFERENCES

Braeutigam, R. R., A. F. Daughety and M. A. Turnquist. 1982. "The Estimation of a Hybrid Cost Function for a Railroad Firm." *The Review of Economics and Statistics*, 64 (3): 394-404.

Braeutigam, R. R. and J. Swanson. 1980. "The Determination of Railroad Costs: Regulatory Issues, Economic Analysis, and Accounting Perspectives." Prepared for the Railroad Cost Seminar, the Interstate Commerce Commission, June 2-3.

Caves, D. W., L. R. Christensen, M. W. Tretheway and R. J. Windle. 1985. "Network Effects and the Measurement of Returns to Scale and Density for U.S. Railroads." In A. F. Daughety, ed., *Analytical Studies in Transport Economics.* Cambridge University Press. New York, N.Y.

Daughety, A. F., M. A. Turnquist and S. L. Griesbach. 1983. "Estimating Origin-Destination Specific Railroad Marginal Operating Cost Functions." *Transportation Research* 17A(6), November, pp. 451-62.

DNS Associates, Inc. 1984. *User Manual: DNS MicroURCS.* Washington, D.C.

Friedlaender, A. F. 1969. *The Dilemma of Freight Transport Regulation.* Brookings Institution, Washington, D.C.

Friedlaender, A. F. and R. H. Spady. 1980. "Economic Costs and the Uniform Railroad Costing System." Prepared for the Railroad Cost Seminar, the Interstate Commerce Commission, June 2-3.

Griliches, Z. 1972. "Cost Allocation in Railroad Regulation," *Bell Journal of Economics and Management Science* Spring: 26-41.

Griliches, Z. 1988. Appendix B in Wesbrook, M. D., "Research Report on URCS Regressions." Bureau of Accounts, Interstate Commerce Commission, Washington, D.C., July 1988.

Hariton, G. 1984. *Railway Costing: A Review.* Research Branch, Canadian Transport Commission).

Interstate Commerce Commission, Bureau of Accounts. Undated. *An Introduction to the Uniform Rail Costing System: Its Development, Functions and Regulatory Role*, Washington, D.C.

Interstate Commerce Commission, Bureau of Accounts. 1981. *Uniform Rail Costing System: Preliminary 1979 Rail Cost Study.* Washington, D.C.

Interstate Commerce Commission, Bureau of Accounts. 1982. *Uniform Railroad Costing System: 1980 Railroad Cost Study.* Washington, D.C.

Interstate Commerce Commission, Bureau of Accounts. 1983. *Uniform Railroad Costing System: Phase III - Movement Costing Program User's Manual.* Washington, D.C.

Interstate Commerce Commission. 1989. Adoption of the Uniform Railroad Costing System as a General Purpose Costing System for all Regulatory Costing Purposes, Ex Parte No. 431 (Sub-No. 1), September 20, 1989.

Irwin, N. A. and L. S. Sims. 1989. "Rail Transportation of Dangerous Goods: Alternative Routes and Operation Strategies for the Toronto Area." *Journal of Transportation Research Forum*, pp. 368-83.

Johnson, M. A. and S. C. Yevich. 1982. "An Overview of the ICC's Uniform Rail Costing System." *Transportation Research Forum*, pp. 379-87.

Keeler, T. E. 1983. *Railroads, Freight and Public Policy.* Brookings Institute, Washington, D.C.

McBride, M. E. 1982. "Economic Costs, Railway Costs and the Uniform Rail Costing System." *Transportation Research Forum.*

Meyer, J. R. and G. Kraft. 1961. "Evaluation of Statistical Costing Techniques as Applied in the Transportation Industries." *American Economic Review*, May.

Meyer, J. R., N. J. Peck, J. Stenason and C. Zwick. 1959. *The Economics of Competition in the Transportation Industries*. Harvard University Press: Cambridge, Mass.

O'Connor, T., J. M. Robinson and W. F. Huncke. 1983. "The Uniform Rail Cost System: Implications for Transportation Management." *Transportation Research Forum*, pp. 368-75.

Railway Age. 1991. "New Hazmat Regulations?" April, pp. 44-5.

Waters, W. G. II and M. W. Tretheway. 1989. "Aggregate Econometric Approach versus the Disaggregate Activity Approach to Estimating Cost Functions." Prepared for the World Conference on Transportation Research, Yokohama, Japan, July 10.

Waters, W. G. II. 1985. "Rail cost analysis." In K. J. Button and D. E. Pitfield, eds., *International Railway Economics*. Gower Publishing Company Limited, England.

Waters, W. G. II and A. D. Woodland. 1984. *Econometric Analysis and Railway Costing*. Centre for Transportation Studies, University of British Columbia, and North Oxford Academic Press, U.K..

Wesbrook, M. D. 1988. "Research Report on URCS Regression Equations." Bureau of Accounts, Interstate Commerce Commission, Washington, D.C.

(July 1988, revised October 1988).

Wolfe, K. E. 1984. "An Examination of Risk Costs Associated with the Movement of Hazardous Materials." Paper presented to *Transportation Research Forum*, pp. 228-40.

18

A TEST OF MARKET BEHAVIOR IN THE TRANSPORT OF PETROLEUM AND LIQUID HAZARDOUS MATERIALS

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ABSTRACT

This article focuses on the nature of conduct in motor carrier transportation of petroleum and liquid hazardous materials (P&LHM) products. A model of the interaction between motor carriers and shippers is constructed. Carriers are assumed to be competitive in the transport of general freight and P&LHM. Shippers of general freight are also assumed to act competitively, but shippers of P&LHM may act either as perfect competitors or as oligopsonists. Predictions about the rate per ton-mile in the industry are generated from the theory, leading to an estimated rate function that can be tested empirically to determine if shippers of P&LHM act competitively or as oligopsonists, and whether shippers of P&LHM products bear greater liability for accidents because of "deep pockets" associated with their large size. Using pooled data from 1985 to 1987, empirical tests suggest that shippers of P&LHM products act no differently from shippers of general freight; there is no statistically significant evidence to support either deep pockets or oligopsony.

1. INTRODUCTION

The Motor Carrier Act of 1980 greatly increased rate competition. The freedom to quote individual rates led to a great deal of discounting from the rates established by motor carrier tariff bureaus. Motor carriers have also had increased freedom to frame contracts with shippers. Since the terms of contracts are not open to the public, it is generally felt that they have also fostered rate competition. Contracts may also have helped shippers and carriers arrange rate and service quality agreements tailored to meet the needs and capabilities of both.

It is hard to find serious, broadly supported objections to motor carrier deregulation by individual shippers and their organizations. Some experts estimate that the reforms saved billions of dollars in transportation expenses. Notwithstanding such claims, an issue that involves economic efficiency and equity remains. It has to do with the possible exploitation of small carriers by large shippers.

There are knowledgeable people in the transportation industries who believe that many large shippers use their economic power to depress rates or force such high quality standards on carriers that they are unable to earn a normal return on their capital. In other words, some shippers are thought to exert monopsony (or oligopsony) power, depressing rates below what they would be in a perfectly competitive market.

Economists tend to respond to such oligopsony suspicions with a skepticism grounded in two basic ideas. The first has to do with the concept of long run equilibrium. That is, in the long run, when capital and other factors are highly mobile, carriers who work for large shippers must earn the same rate of return as that earned in transporting the freight of the tens of thousands of other shippers of manufactured and agricultural goods who together originate as much freight as the large shippers. Otherwise, there would be insufficient capacity to haul the goods of large shippers.

The second ground for the economist's wariness of the oligopsony position is that motor carrier equipment is highly mobile even in the short run. It can be moved with relative ease from one kind of service and geographic area to others. Hence, the exercise of oligopsony power may not be possible even in the short run.

We share the view held by economists that the long run exercise of oligopsony power in motor carrier transportation is not possible. However, at the outset of this investigation we felt that it could possibly exist in the transport of liquid products by tank trucks in the short run. Neither the equipment nor the terminal facilities used in such transport is readily transferrable to other types of transport, such as the movement of general commodities. The present investigation has been carried out to shed light on the question of whether oligopsony power is exercised in the transport of liquid products.

The question is important because, among other things, it bears on issues of safety. If rates and returns are depressed in this sector, one that handles some of the most dangerous of the hazardous materials, those motor carriers that are most careful about hours of service, the hiring and training of drivers, and who generally excel in their management of safety may be repelled, leaving the field to high risk firms.

Our analysis begins in section 2 with the specification of a model of the interaction between shippers and carriers. Here we allow for two possible factors that in equilibrium might affect the transport rate charged by carriers. First, there is the possibility that shippers exercise oligopsony power; for example, if shippers of liquid products exercise monopsony (or oligopsony) power and general freight shippers do not, then rates for liquid products would be lower than those for general commodities, everything else being equal.

Second, we allow for the possibility that very large shippers of liquid products may be saddled with a larger portion of the liability resulting from transport accidents than their counterparts among general freight shippers. This might occur if carriers of liquid petroleum products are able to pass along larger portions of such accident costs than carriers of general freight, or if those damaged in accidents involving liquid product movements more often obtain recovery of damages directly from shippers. In such cases the liquid product shippers could be said to have relatively deep pockets. The basic idea here is that if everything else were equal, in equilibrium transport rates ought to be lower in an industry in which shippers have relatively deep pockets.

Section 2 indicates how one might examine a function relating the rate per ton-mile to a number of variables to see if rates are systematically lower for the liquid product carriers, in which case one might suspect the existence of either oligopsony power or deep pockets. In section 3 we briefly describe the data used to examine the rate function, and in section 4 we summarize the empirical findings. Using pooled data from 1985 to 1987, empirical tests suggest no evidence that shippers of liquid products act differently from shippers of general freight. This conclusion holds for estimates of both short run and long run rate functions.

2. A MODEL OF THE INTERACTION OF SHIPPERS AND CARRIERS

We now construct a model of market interaction between shippers and motor carriers. The purpose of this exercise is to generate a testable hypothesis that will serve as the basis for the empirical tests in section 3. In the model that follows, we focus on the way in which transport rates vary depending on the behavior of shippers and on the way in which liabilities associated with accidents are distributed between shippers and carriers.

Let us begin by stating a set of assumptions. In the suggestive theoretical model, we assume that in a particular market, such as the market for transporting P&LHM, there are many carriers and shippers. As a maintained hypothesis we assume the motor carrier industry to be competitive, for carriers of both general freight and P&LHM.

In the empirical work we estimate both short run and long run rate functions for motor carriers. The short run formulation allows for the possibility that carriers cannot adjust their capital stock to an optimal (cost minimizing) level within the yearly time horizon from which the data are drawn. Each motor carrier faces a set of factor prices and has a given amount of capital in place. All factors except capital can be varied to optimal levels within the yearly time horizon. While the theoretical development below is presented for the short run, the parallel long run development (in which the level of capital can be chosen optimally as well) is omitted in the interest of brevity.[1]

Consider the inverse supply function for the motor carrier industry, assuming that no litigation occurs in connection with accidents. Let Y denote the total ton-miles that carriers in the market supply. Suppose shipper i wishes to transport y_i ton-miles. In the short run the rate that the motor carrier industry will require per ton-mile for shipper i's traffic will depend on a number of things. These include the factor prices (w^i) and amount of capital in place (k_i) faced by the carrier hauling shipper i's freight. The rate may also depend on the total ton-miles Y being transported by all carriers in the industry, where

$$Y = \sum_{i=1}^{m} y_i \quad .$$

It will also reflect the level of safety (accident prevention effort) that shipper i requires in connection with its traffic. We denote that level of safety by q_i, where q_i can be thought of as one possible measure of quality of service.[2] The transport rate will also be a function of the characteristics of the traffic being carried, such as average length of haul and average load per shipment; these traffic characteristics are represented as a vector of hedonic measures D_i. Formally, the short run inverse supply schedule (rate function) for the traffic of shipper i can be represented as in (1).

$$r^i = g(Y)h(q_i, w^i, k_i, D_i) \tag{1}$$

Several remarks about this specification are in order. If, as is normally assumed, the industry supply schedule is upward sloping in output, then the derivative $g' > 0$.[3] (If the supply schedule were "flat," with $g' = 0$, there would be no oligopsony power in the industry.) One would also expect that a higher rate would be necessary to induce carriers to provide a higher level of service quality q_i; thus we assume

$$h_{q_i} > 0.$$

In addition, one might normally expect that the carriers' marginal cost of increasing service quality rises as quality increases, so that

$$h_{q_i q_i} > 0.$$

One would also expect that when each firm has more capital in place, the short run marginal cost of production will be lower since fewer additional variable inputs will be needed, so that $h_k < 0$. Finally, since a higher factor price for factor $j(w^i_j)$ will typically increase the marginal cost of production, we assume that $h_w > 0$.[4]

Now we add to the formulation the possibility that if there are accidents, damages are incurred. Suppose that the probability of an accident per ton-mile shipped is $f(q_i)$.[5] Let H represent the expected size of damages resulting from an accident. Then for shipper i's traffic, the expected damages per ton-mile hauled are $f(q_i)H$.

We next come to the issue of liability. Who pays for damages when there is an accident? Assume that when an accident occurs, some portion (ß) of the damage is assigned to the shipper, and the balance (1-ß) is covered by the carriers. An industry in which ß is higher will be said to be one in which the shippers have deeper pockets.

In a world of competitive transport supply, the rate that carriers will require if they are to provide a level of safety q_i will need to cover not only the production costs indicated in (1), but also that portion of the expected damages that the carriers will have to cover themselves. Thus (1) will have to be augmented as follows:

$$r^i = g(Y)h(q_i, w^i, k_i, D_i) + (1-\beta)f(q_i)H \tag{2}$$

Now we turn to the decision of shipper i. Suppose shipper i produces z_i units of output. For simplicity we assume the shipper's only input is transportation, so that revenue depends only on the amount of transport purchased (and in turn on the level of z_i). If shipper i chooses y_i ton-miles of transportation, revenues will be $R(y_i)$. At the same time, if y_i and q_i are chosen, transport costs will be

$$t^i = y_i[g(Y)h(q_i,w^i,k_i,D_i) + (1-ß)f(q_i)H] \tag{3}$$

Finally, shippers must recognize that they absorb that portion of the expected damages from accidents that is not covered by the carriers, namely $y_i ß f(q_i)H$. The profit for shipper i is thus

$$\pi^i = R(y_i) - y_i[g(Y)h(q_i,w^i,k_i,D_i) + (1-ß)f(q_i)H] - y_i ß f(q_i)H$$

$$= R(y_i) - y_i g(Y)h(q_i,w^i,k_i,D_i) - y_i f(q_i)H \tag{4}$$

The expression for the profit of the shipper therefore does not depend on ß. This holds since if carriers are competitive, damages assigned to carriers will be passed on to shippers either through the rate structure or directly through liability. This is not to suggest that the liability parameter ß ceases to be important in the analysis. Since ß is present in (3), it will reenter the picture later when we address the transportation rates charged by the carriers.

Endogenous Quality

We assume the shipper seeks to maximize profit, as stated in (4). We have not yet addressed the issue of how the level of safety is set. Two possibilities will be examined here. First, we suppose that each shipper specifies the level of safety (q_i) that must be used in connection with its traffic, so that quality of service is endogenous to the transport market equilibrium. A second possibility is that the level of safety is specified by some exogenous means, such as through a set of regulations imposed on the industry. Since the comparative statics predictions for the empirical work could in principle depend on whether the level of safety is more appropriately treated as endogenous or exogenous, we perform the analysis under both scenarios.

With endogenous safety, shipper i goes to the motor carrier industry, indicates how much traffic it wants moved and the level of safety that must be offered, and then pays whatever transport rate is required. If each shipper (i=1,...,m) chooses y_i and q_i to maximize its profits, then the first order conditions for optimality will be as follows[6]:

$$\pi^i_{y_i} = R_{y_i} - gh - y_i hg'(1+\alpha_i) - fH = 0 \qquad i = 1,...,m \tag{5}$$

$$\text{and} \quad \pi^i_{q_i} = -y_i h_{q_i} g - y_i f'H = h_{q_i} g - f'H = 0 \qquad i = 1,...,m \tag{6}$$

While a number of game theoretic approaches might be used to capture the essence of oligopsonistic behavior (if it exists), here we employ a standard conjectural variations approach, in which α_i represents shipper i's conjecture about the effect of a change in y_i on the shipments by the rest of the shippers in the industry. The conjectural variation can be represented as

$$\alpha_i = \sum_{j \neq 1}^{m} dy_j/dy_i$$

Three special cases for α are worth mentioning here. If $\alpha = 0$, the conjectural variation represents the Cournot oligopsony equilibrium, since shipper i does not believe a change in its own output will affect the output of other shippers. If $\alpha = -1$, the conjectural variation represents the competitive equilibrium, since shipper i believes that any change in its own output will be exactly offset by an equal and opposite change in the total output of the rest of the industry (and hence price will remain unchanged as shipper i adjusts its own output). If $\alpha = (m-1)$, the conjectural variation represents the perfect monopsony equilibrium.

An equilibrium in the industry will then be characterized by (5), (6) and the additional adding up condition represented by (7).

$$Y = \sum_{i=1}^{m} y_i \tag{7}$$

To develop some testable hypotheses in a simplified framework, suppose all carriers are alike, so that we may focus on a symmetric industry outcome. When shippers are alike (including having identical conjectural variations so that $\alpha_i = \alpha_j = \alpha$, as well as the same revenue functions R and the same levels of k and D), in equilibrium the choice of y_i and q_i will be identical for each shipper. Thus for the balance of the theoretical presentation, $\pi^i = \pi^j = \pi$, $q_i = q_j = q$, and $y_i = y_j = y = Y/m$ for all i and j. The conditions characterizing a symmetric equilibrium can be written as in (8) and (9), where (my) has been substituted for (Y) to incorporate the symmetry condition of (7).

$$\pi_y = R_y - g(my)h - yhg'(my)(1+\alpha) - fH = 0, \quad i = 1,...,m \tag{8}$$

and $$\pi_q = - yh_q g(my) - yf'H = -h_q g(my) - f'H = 0, \quad i = 1,...,m \tag{9}$$

There are many possible comparative statics derivatives that can be examined, given the structure now in place. Endogenous variables include among others y, q, π and r; exogenous variables include among others w, D, α, ß, H, m and k. With an eye toward the available data, we focus here only on the comparative statics results that will be of most interest in the empirical work.

The first question to be explored is whether shippers of P&LHM behave any differently from shippers of general freight. Ultimately in the empirical work we shall estimate a rate function, r, which will depend on all of the observable exogenous variables w, D, H and k, as well as whether the shipments involved are general freight or P&LHM movements. In addition, r will depend explicitly on one endogenous variable, the industry output Y, to control for industry size. There are two other exogenous variables that we would like to include, α and β; unfortunately, neither of these two variables can be directly observed. We therefore regress the rate r on w, D, H, k, Y and a dummy variable for shipments of P&LHM. Thus, if there are systematic differences in the reduced form rate function between shippers of P&LHM and shippers of general freight, the differences will be attributed to variations of α and β between the two types of shippers.[7]

How will variations in the liability parameter β affect the reduced form rate function? The answer can be seen from an examination of the derivative

$$dr/d\beta = hg'(my)mdy/d\beta + [g(my)h_q + H(1-\beta)f'']dq/d\beta - fH, \tag{10}$$

where $dY/d\beta = mdy/d\beta$ since there are m shippers, each shipping y units. As noted above, since β does not enter into the shipper's profit maximization, $dy/d\beta=0$ and $dq/d\beta=0$. Hence, $dr/d\beta = -fH < 0$. If shippers of P&LHM have deeper pockets than shippers of general freight, the rate function will be lower since shippers of P&LHM will pay less as they have to absorb more liability directly. Thus, deep pockets will tend to make the coefficient of the dummy variable representing movements of P&LHM negative.

What can be said about the effect of variations in the conjectural variations parameter α? Since we have assumed (by maintained hypothesis) that general freight shippers are competitive, the value of α associated with their behavior is assumed to be -1. If shippers of P&LHM behave competitively, the value of α associated with their behavior will also be -1. If, however, these shippers behave as oligopsonists, $\alpha > -1$. We cannot observe α directly, but we can derive the implications of an increase in α on the rate per ton-mile that carriers will receive. Formally,

$$dr/d\alpha = hg'mdy/d\alpha + [gh_q + H(1-\beta)f'']dq/d\alpha \tag{11}$$

This in turn requires the evaluation of the derivatives $dy/d\alpha$ and $dq/d\alpha$. It can be established that $dy/d\alpha < 0$ and that $dq/d\alpha \geq 0$.[8] With these derivative values, when $g'>0$ and there is oligopsony (i.e., $\alpha > -1$), the first term of (11) will be negative and the second term will be positive when $\beta>0$ and zero when $\beta=0$. Thus, $dr/d\alpha$ will be positive if there is no oligopsony power, but could be negative if there is oligopsony power. If $g'=0$, then $dr/d\alpha = 0$.

These comparative statics results lead us to state the following testable hypothesis:

<u>Testable Hypothesis:</u> If the coefficient on the dummy variable associated with P&LHM shipments in the estimated rate equation is negative, then either (i) shippers of P&LHM exhibit oligopsony power, or (ii) more of the liability from P&LHM accidents is shifted to shippers.

This is the central testable hypothesis we examine in the next section. The negative sign suggested by theory under oligopsony is consistent with economic intuition. Oligopsony power on the part of shippers would be expected to decrease the transport rate. Note that the empirical test of the coefficient of the dummy variable on P&LHM shipments is a joint test of oligopsony power and deep pockets. The null hypothesis is that there is no market power and that no more liability is shifted to shippers of P&LHM than is the case with general freight. A negative coefficient on the dummy variable for shippers of P&LHM will lead to an inference of oligopsony power or deep pockets, although we cannot identify which effect causes the negative coefficient.

Using the model, it is also possible to derive other comparative statics predictions on the signs if the derivatives of the rate function that can be estimated. In general dr/dw_i is not determinate, although one might normally expect higher factor prices to lead to higher rates.[9] Similarly, one might normally expect transport rates to rise as income shifts the demand for transportation out, so that $dr/dI > 0$. However, if there is oligopsony power ($\alpha > -1$) or some liability shifting ($\beta > 0$), or if an increase in income does not shift out the marginal revenue schedule for the shipper, then dr/dI could take on any sign.[10] Finally, the sign of dr/dH is indeterminate, although one might normally expect higher rates to follow from more costly accidents. The indeterminacy arises because shippers will cut back the amount shipped as H rises (leading to lower rates), but at the same time they require a higher level of safety (tending to increase rates).[11]

Exogenous Quality

If the level of safety is specified by some exogenous means, such as a set of regulations imposed on the industry, the analysis of the comparative statics is simpler, and the comparative statics predictions are somewhat stronger. The firm chooses y_i to maximize profit (4), taking the level of safety as given. The first order profit maximizing condition on quantity remains as in (5).

With regard to liability shifting, $dy/d\beta=0$; shippers do not alter their demands as liability is shifted since they pay for liability either directly or through the transport rate. As a result, $dr/d\beta= hg'mdy/d\beta -fH<0$; as liability shifts to shippers, the transport rate shippers are willing to pay will fall, just as was the case with endogenous safety.

Other comparative statics properties can be derived as follows. If shippers become more oligopsonistic, then the transport rate should fall (i.e., $dr/d\alpha < 0$).[12] If the expected cost of an accident rises, then shippers cut back on the quantity shipped ($dy/dH<0$) and transport rates may either rise or fall (dr/dH may be positive or negative).[13] If income rises and shifts out the marginal revenue schedules for shippers and if $g'>0$, then the amount shipped rises ($dy/dI>0$) and the transport rate would be expected to rise.[14] Finally, if shippers behave competitively, an increase in a factor price will lead to a higher transport rate in equilibrium ($dr/dw_j >0$ when $\alpha=0$); however, if α>-1, then dr/dw_j can be positive or negative.[15] A negative sign on a factor price in the estimated rate equation would suggest that oligopsony power is present.

Although we cannot determine whether the level of safety is endogenous or exogenous, in either case the foregoing analysis leads to one primary test that can be performed on the coefficient of the dummy variable for P&LHM products. As the theory suggests, if this coefficient is negative, there is evidence of either oligopsony power or deep pockets. The signs of the other coefficients will also be examined in the empirical analysis below to see if there is any other evidence of deep pockets or oligopsony power.

3. THE DATA

The data consist of annual observations on 244 motor carriers over a three year period (1985-1987). The primary source of data is provided by the American Trucking Associations (1985-87) which compile summary tables from reports the carriers file with the Interstate Commerce Commission.

Of the 244 firms, 156 are motor carriers that work with liquids exclusively, specifically petroleum products and liquid hazardous materials. Four of these 156 firms classify their primary commodity as hazardous materials.

The other 88 firms are general freight carriers. All of these firms have truckload (TL) and less than truckload (LTL) traffic. TL shipments involve the use of a truck that makes a pickup and goes directly from a shipper's origin to a destination. LTL traffic involves smaller shipments, and typically a higher rate per ton-mile. They require a movement to a terminal where they are consolidated into a trailer that has numerous shipments bound for a given destination. The firms in the sample have LTL operations that range from 10 to 96 percent. The percentages are computed in terms of tons because a breakdown of ton-miles into TL and LTL traffic is not published for individual carriers. None of the 156 tank truck carriers have any LTL movements.

With respect to the reduced form rate equation to be estimated, the dependent variable for a carrier (r_i) is the rate per ton-mile. This is defined as the total operating revenue divided by ton-miles.[16] The rate per ton-mile was deflated by the Producer Price Index (PPI).

Dependent variables in the short run rate equation included three factor prices (the w_j variables), all expressed as expenditures per ton-mile. While it would be preferable to have the factor prices expressed in more conventional ways (e.g., dollars per gallon of fuel, dollars per worker-hour), such measures were unavailable at the firm level. The factor price of labor is defined as salaries and wages of drivers and helpers per ton-mile.[17] The price of fuel is defined as expenditures on fuel per ton-mile.[18] The price of insurance is defined as the expenditures on insurance per ton-mile. For the short run formulation we required a measure of the quantity of capital (k). Here we employed the total number of power units (trucks and tractors) in operation.

We also examined a long run rate equation, including the price of capital instead of the amount of capital for each carrier. The price of capital attempts to measure the truck rental price faced for each carrier, and is defined as the expenditure on vehicles rented without a driver divided by the number of miles operated with these trucks. (The number of observations declines noticeably in this case because many carriers did not report rental expenditures.)

Three hedonic measures (the D_i variables) are included in the estimation. These included (1) the average length of haul, defined as total ton-miles divided by total tons, (2) the average weight of a load, defined as total ton-miles divided by total miles, and (3) the percent of LTL tons of freight, defined as LTL tons divided by total tons. As noted in the discussion above, this will be zero for all tank carriers.

To measure the expected size of damages (H), we would have liked to have data on property damage per ton-mile for each firm. However, the available data contained only the total amount of property damage per accident by type of carrier. The amount of property damage per accident varies only across the two types of firms (liquid carriers and general freight carriers) for each of the three years.[19] Although we used this measure in the regression analysis, we note that property damage per ton-mile will equal property damage per accident only if accidents per ton-mile are equal across firms. Firm-specific data would improve the analysis in this respect.

A measure of the macroeconomic level of economic activity is the value of gross national product.

4. EMPIRICAL RESULTS

All of the variables discussed in the previous section (with the exception of the hedonic measure of the percent LTL and the Tank Dummy variable) are entered into the rate function shown in table 1 in log form. Both short run and long run regressions are reported in the table. All of the independent variables in the regression are assumed to be exogenous, except for industry output (Y). We therefore executed the regression using instrumental variables, where the instruments for Y included all of the exogenous variables in table 1 plus a one-year lagged value of Y.

In addition to the variables already identified, "Tank Dummy" takes on a value of "1" if the firm is one of the 156 tank carriers, and "0" otherwise. All of the variables in the table following "Tank Dummy" are interaction terms.

An estimate of primary interest is the coefficient on Tank Dummy, since a negative and statistically significant coefficient would suggest either deep pockets or oligopsony. The point estimate is statistically insignificant in both the long run and short run regressions.[20] Thus, we cannot reject the hypothesis that shippers of liquid products behave any differently from general freight shippers, which we have taken by maintained hypothesis to act competitively.

Other variables are largely consistent with expectation. First consider the short run results. For the base case (general freight carriers), the factor price coefficients on labor and insurance are positive and statistically significant. The coefficients on the hedonic measures suggest that in equilibrium, the rate per ton-mile is lower for

Table 1. Regression Results
Dependent Variable: Rate per Ton Mile

Independent Variable	Short Run Rate Equation Coefficient	Short Run Rate Equation T-statistic	Long Run Rate Equation Coefficient	Long Run Rate Equation T-Statistic
Constant	-10.4239	-0.9895	5.1531	0.2763
Log Price of Labor	0.4155	7.4528	0.3455	2.0186
Log Price of Fuel	0.0416	0.6308	-0.0203	-0.0879
Log Price of Insurance	0.1804	4.0039	0.1986	2.3201
Log Amount of Capital	0.0409	2.4943		
Log Price of Capital			0.0290	1.1928
Log Length of Haul	-0.2543	-3.8549	-0.2580	-2.0856
Log Weight of Load	0.0087	0.1576	-0.0805	-0.6560
Percent LTL	0.5956	4.8516	0.6944	2.0400
Log Damage	-0.4530	-0.7426	-0.1792	-0.1451
Log Industry Output	0.2854	0.7770	-0.4137	-0.5280
Log GNP	0.9125	0.4690	0.3888	0.1004
Tank Dummy	-0.8501	-1.1660	-3.2778	-1.8811
Tank*Log Price of Labor	-0.3347	-5.4115	-0.1589	-0.8881
Tank*Log Price of Fuel	-0.0620	-0.8649	-0.0932	-0.3960
Tank*Log Price of Ins.	0.0931	1.8634	-0.1490	-1.6746
Tank*Log Length of Haul	0.2023	2.9317	0.1945	1.5213
Tank*Log of Load	-0.6743	-10.1615	-0.7918	-5.7652
Tank*Log Capital	-0.0787	-3.7533		
Tank*Log Price of Capital			0.0709	2.3482
R-Squared	0.92		0.93	
Number of Observations	543		160	
Degrees of Freedom	525		142	

general freight carriers with longer hauls on average and higher for carriers with a larger portion of LTL shipments. For P&LHM shippers, rates do not appear to decline with length of haul (since the coefficients on the Log Length of Haul and Tank*Log Length of Haul variables are approximately equal in magnitude and of opposite sign).

Another result of some interest is that the coefficient on the term involving industry output is insignificant at the 5% level. This suggests that even in the short run the industry rate schedule is rather elastic. This result is consistent with the insignificance of the Tank Dummy variable; if the industry supply schedule is quite elastic, there will be no opportunity for P&LHM carriers to exercise oligopsony power.

For the long run rate function, the results are quite similar. As noted above, the tank dummy remains insignificant. Further, the rate does not appear to depend significantly on the level of industry output.

There are, of course, a number of potential difficulties encountered in the current study. To a great extent, the difficulties come from data that are not as good as one might desire. For example, as we have already noted, one would like to have better measures of factor prices at the firm level, rather than the ones computed here based on expenditures per ton-mile. We would also like to have a better measure of the damages incurred by individual firms, rather than the measures we have used (an average for either P&LHM carriers or general freight carriers at the industry level).

While we do have a panel data set, we are not in position to examine the possibility of firm-specific effects in the error term. The standard econometric procedure for removing firm-specific components in the error structure involves mean differencing the data over the cross section. One of the consequences of this technique is that the constant term in the regression should be zero, so that it is meaningless to test whether the constant terms in the rate functions associated with two subsamples (in our case general freight and P&LHM) are different; hence, we have not attempted to deal with firm-specific components in the error structure since we wish to test whether the Tank Dummy variable is significant. We note here that if there are such firm-specific effects, and if they are correlated with a regressor, then there may be a bias in the estimated coefficient of that regressor.

5. CONCLUSIONS

Using pooled data from 1985 to 1987, empirical tests conducted here suggest two main findings in addition to others discussed at greater length in the text. First, there is no evidence that shippers of liquid products act differently from shippers of general freight; thus we find no support for either oligopsony power or deep pockets for these shippers. Second, the empirical analysis sheds some light as to why oligopsony power might not exist; even in the short run (using data drawn from an annual horizon) the industry rate schedules are quite elastic for both general freight and P&LHM carriers. If the industry supply schedule is quite elastic, there will be no opportunity for P&LHM carriers to exercise oligopsony power. These conclusions hold for both the long run and short run formulations of the estimated rate function.

We have noted a number of empirical problems that might be corrected or better addressed with better data. These include a desire for better measures of factor prices, a firm-specific measure of the costs associated with accidents, and a longer time series that might allow for an investigation of firm-specific components in the error structure as well as an examination of possible autocorrelation.

REFERENCES

American Trucking Associations. 1990. *Transportation in America*. Eighth Ed., May.

American Trucking Associations. 1985, 1986, 1987. *Financial and Operating Statistics Motor Carrier Annual Report.*

United States Department of Commerce, Bureau of Census. 1985-87. *Current Industrial Reports*, "Truck Trailers."

United States Department of Transportation. 1990. *National Transportation Statistics - Annual Report.* July.

United States Department of Transportation, Office of Motor Carriers. 1985-1987. *Accidents of Motor Carriers of Property.*

American Trucking Associations. 1985, 1986, 1987. *Financial and Operating Statistics Motor Carrier Annual Report.*

ENDNOTES

1. The primary comparative statics results developed below (how oligopsony power and deep pockets affect transport rates) are not affected by whether we use a long run or short run formulation.

2. Of course, there are many other possible measures of quality of service, including among other things reliability, extent of loss and damage, and responsiveness to complaints. These other measures of quality are not considered explicitly in the analysis here.

3. Partial derivatives of variables with a single variable will be denoted by a prime (′) symbol in the text; partial derivatives of variables with more than one argument will be denoted by subscripts. For example, g' denotes $\partial g/\partial Y$, and

$h_{w_j^i}$ denotes $\partial g/\partial w_j^i$.

4. If the appropriate specification of the supply function involved the long run instead of the short run, the long run inverse supply schedule could be written as $r^{iL} = g^L(Y)h^L(q_i, w^i, w_k^i, D_i)$, where the superscript L denotes the long run, and the supply schedule would depend on the factor price of capital w_k^i instead of k. The primary comparative statics properties discussed below will have the same signs whether generated from a long run or a short run supply schedule. However, the distinction between the long run and short run becomes more important in the empirical analysis of section 4, where the appropriate reduced form for estimation must be specified.

5. We also assume that $f' < 0$ since a higher level of safety will reduce the probability of an accident.

6. Where the arguments of functions are unambiguous, they are suppressed to simplify notation wherever possible.

7. As is usual with such an approach, one must acknowledge the possibility that the dummy variable could reflect systematic differences between general freight and HM&LP carriers due to any left out variables other than α and β.

8. The development of these derivative properties is as follows. Using the definitions of π in (7) and(8), let $\Omega = \pi_{yy}\pi_{qq} - (\pi_{yq}\pi_{qy})^2$. We assume $\pi_{yy} < 0$, $\pi_{qq} < 0$ and $\Omega > 0$ for all values of α such that $-1 \leq \alpha \leq (m-1)$; this assumption is not equivalent to the concavity of π in y and q since the symmetry condition (y=my) has been imposed in equilibrium. First assume $g'>0$. It then follows that $dy/d\alpha = [\pi_{y\alpha}\pi_{qq} - \pi_{q\alpha}\pi_{yq}]/\Omega$. Since $\pi_{q\alpha}=0$, then $\pi_{y\alpha} = -yhg'<0$, and, $dy/d\alpha <0$. Similarly, $dq/d\alpha = [\pi_{yy}\pi_{q\alpha} - \pi_{yq}\pi_{y\alpha}]/\Omega$. It then follows that $dq/d\alpha < 0$ when $\alpha>-1$, and $dq/d\alpha = 0$ when $\alpha=-1$. Finally, if $g'=0$, theory predicts $dr/d\alpha = 0$ (since $\pi_{y\alpha} = \pi_{q\alpha}=0$).

9. To see this, note that $dr/dw_j = hg'mdy/dw_j + [gh_q + H(1-\beta)f']dq/dw_j + gh_{wj}$. The last term is positive. Using standard comparative statics procedures (the details are omitted here), it can be shown that the signs of dy/dw_j and dq/dw_j and dr/dw_j are ambiguous.

10. Briefly, $dr/dI = hg'mdy/dI + [gh_q + H(1-\beta)f']dq/dI$. The value of this derivative will depend on the R_{YI}, which one might normally assume to be positive, so that a higher level of income shifts the marginal revenue schedule out. It can be shown that when $R_{YI}>0$, $dy/dI>0$ and $dq/dI<0$. If $\alpha=-1$ and $\beta=0$, then $dr/dI>0$. Otherwise, the sign of dr/dI is not determinate.

11. Formally, $dr/dH = hg'mdy/dH + [gh_q + H(1-ß)f']dq/dH + (1-ß)f$. It turns out that $dy/dH<0$ and $dq/dH>0$ for all α. The first term will be negative, the last term positive, and the middle term positive when $ß>0$. Thus the sign of dr/dH is indeterminate. However, if $g'= 0$, then the first term is zero, so that $dr/dH>0$.

12. From (5) we obtain $dy/d\alpha = -\pi_{y\alpha}/\pi_{yy} <0$. Then $dr/d\alpha = hg'mdy/d\alpha < 0$.

13. From (5) it follows that $dy/dH = -\pi_{yH}/\pi_{yy} = f/\pi_{yy}<0$. Then $dr/dH = hg'mdy/dH + (1-ß)f$. The first term is negative and the second term is positive, so that the sum is indeterminate. Note that if all accident costs are shifted to the shippers ($ß=1$) and the rate schedule is increasing in y ($g'>0$), then the $dr/dH<0$, since the second term is zero. If $g'=0$ and $ß=1$, $dr/dH=0$. If $g'=0$ and $ß<1$, then $dr/dH>0$.

14. If $R_{YI}>0$, then $dy/dI=-R_{YI}/\pi_{yy}>0$ and $dr/dI = hg'mdy/dI>0$.

15. From (5) it follows that $dy/dw = -\pi_{yw}/\pi_{yy} <0$. Then $dr/dw = hg'mdy/dw+h_{wj}$. The first term will be negative and the second term will be positive, so that in general the sum is indeterminate. However, when $\alpha = 0$, $dy/dw_j = gh_{wj}/(R_{yy}-g'hm)<0$ and $dr/dw_j = ghw_j[R_{yy}/(R_{yy}-g'hm)]>0$. Similarly, if $g'=0$, $dy/dw_j > 0$.

16. All dollar values in this analysis are expressed in 1982 dollars unless otherwise noted.

17. These were deflated to a 1982 basis using the "Employment Cost Index for Blue Collar Workers," obtained from Table 674 of the *Statistical Abstract of the United States*, 1990.

18. These were deflated to a 1982 basis using the retail price of truck diesel, obtained from United States Department of Transportation, *National Transportation Statistics - Annual Report* (1990).

19. The data for this series was obtained from the United States Department of Transportation (1985-1987).

20. In this article tests of significance will be carried out at the 0.05 level.

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