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Analysis of Human Factors Effects on the Safety of Transporting Radioactive Waste Materials

Technical Report

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ABSTRACT

This report examines the extent of human factors effects on the safety of transporting radioactive waste materials. It is seen principally as a scoping effort, to establish whether there is a need for DOE to undertake a more formal approach to studying human factors in radioactive waste transport, and if so, logical directions for that program to follow.

Human factors effects are evaluated on driving and loading/transfer operations only. Particular emphasis is placed on the driving function, examining the relationship between human error and safety as it relates to the impairment of driver performance. Although multi-modal in focus, the widespread availability of data and previous literature on truck operations resulted in a primary study focus on the trucking mode from the standpoint of policy development.

In addition to the analysis of human factors accident statistics, the report provides relevant background material on several policies that have been instituted or are under consideration, directed at improving human reliability in the transport sector. On the basis of reported findings, preliminary policy emphasis areas are identified.

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FOREWORD

The National Waste Terminal Storage Program was established in 1976 by the U.S. Department of Energy's predecessor, the Energy Research and Development Administration. In September 1983, this program became the Civilian Radioactive Waste Management (CRWM) Program. Its purpose is to develop technology and provide facilities for safe, environmentally acceptable, permanent disposal of high-level waste (HLW). HLW includes wastes from both commercial and defense sources, such as spent (used) fuel from nuclear power reactors, accumulations of wastes from production of nuclear weapons, and solidified wastes from fuel reprocessing.

The information in this report pertains to transportation studies within the Office of Storage and Transportation Systems in the CRWM Program.

EXECUTIVE SUMMARY

This study was carried out at the request of the Department of Energy's (DOE) Office of Civilian Radioactive Waste Management for the purpose of determining the extent of human factors effects on the safety of transporting radioactive waste materials. The intent of this effort was to establish whether there is a need for DOE to undertake a more formal program in the area of human factors in transportation, and if so, logical directions for that program to follow. As such, it was envisioned as a scoping effort, directed at reporting of preliminary findings.

Although truck, rail and barge modes were considered in this analysis, a primary emphasis was placed on truck operations due to more widespread availability of accident data and prior human factors studies focusing on the trucking industry. The study was also restricted to driving and loading/transfer operations. Unloading operations at a monitored retrievable storage facility or geologic repository were assumed to constitute separate activities.

Several accident databases were obtained and reviewed for the purpose of exploring the relationship between human factors and accident characteristics. Unfortunately, since the historical database of transport accidents involving radioactives was sufficiently small, commodity and container definitions had to be expanded to include those which resemble radioactive waste shipments in order to increase the sample size.

Concurrent with efforts to identify and analyze relevant accident data, an extensive literature review was undertaken to search for previous studies related to human factors in transportation that might be relevant to the safe transport of radioactive wastes. As in the case of the database review, it became readily apparent that considerably more information is available on human factors in truck transport than for rail and barge operations.

From analyses of accident data, it is apparent that human error is a leading cause of accidents involving the transport of materials in containers that resemble radioactive waste shipments. It can be inferred from these results that human factors effects on radioactive waste transport operations are likely to be significant to the point where a more formal DOE human factors research program and program policies should be established. While one can argue over an apparent lower accident severity associated with human factors-related accidents, both loading and in-transit, the high frequency of such events coupled with the public perception of a nuclear accident independent of severity, suggests that the occurrence of these accidents should be kept to an absolute minimum.

Having established the scale of the human factors problem, attempts were made to obtain more detailed information from which to identify significant or emerging human factors issues that might threaten the safety of radioactive waste shipments. The availability of detailed truck accident data, coupled with rather extensive outside literature on human factors in the trucking industry, led to a decision to fully develop an understanding of these considerations for truck transport, with more limited attention devoted to rail and barge operations.

Several findings can subsequently be reported. It is apparent that the driver is most frequently the key factor in determining whether or not a vehicular accident occurs under difficult driving conditions. A large number of heavy-truck drivers involved in accidents have poor driving records, including speeding offenses and other unsafe maneuvers that are major causes of accidents. Moreover, the correlation between drivers under the influence of alcohol with increased accident likelihood and severity is a major safety concern.

Accident studies and driver surveys also indicate that a major portion of the heavy-truck driver population has not received any driver training prior to going on the road. Young, inexperienced drivers are particularly susceptible to accident risk.

Fatigue can play a major role in accidents, particularly for young drivers during early shift hours and older drivers after extended shift length. Drivers of large trucks have shown significant increases in driving errors and decreases in driver alertness due to fatigue well within the current hours-of-service limit. Greater understanding of the circadian rhythm (time-of-day) impact on fatigue also suggests that current hours-of-service regulations and management assignment practices need additional examination.

Vehicle design and operating characteristics have a significant impact on the margin of safety within which human tasks must be performed. Brake systems are most in need of attention, with brake maintenance a principal concern. The prevention of jackknifing also deserves special attention. Handling and stability problems increase the likelihood of rollover; tire condition and performance are also key factors in safely handling a big rig. Occurrences of override/underride, particularly at night, are common, suggesting that trailer design and visibility are issues that warrant close attention. Truck occupants typically do not protect themselves by wearing seat belts. As a result, ejection and contact with the cab interior often occur, leading to a higher likelihood of a serious injury or a fatality. Furthermore, truck operators are subjected to noise, vibration and other effects of prolonged truck driving which lead to performance degradation and health impairment.

The roadway environment is also recognized as a vital part of the safety equation. U.S. and State highways are significantly overinvolved in fatal heavy-truck accidents where the absence of sturdy median barriers has a profound impact on safety. The need for cars and trucks to share the roads safely deserves attention. The driving public must be made more fully aware of the handling characteristics of heavy trucks and the potentially life-threatening consequences of a multiple-vehicle crash.

Although relatively little is known about human factors in railroad and barge operations in comparison to the trucking industry, reported findings are remarkably consistent. Consequently, truck, rail and barge transport appear to share many common human factors problems which may require policy intervention.

In terms of container-related areas, these problems focus on securing valves, fittings and closures during the loading process, and making sure they remain snug throughout the in-transit portion of the trip; maintaining internal container pressure within safe limits; safe handling of radioactive materials during the loading process; and proper protection of the shipment from damage should a vehicular accident occur while in-transit.

The human tasks associated with the safe loading and transport of radioactive wastes require individuals who are responsible, qualified, and alert, with a positive attitude towards safety and a level of maturity commensurate with the hazardous nature of the material they are handling. It also requires a carrier management that has made a sincere commitment to safety in its operation, and has made every effort to comply with Federal safety regulation governing the transport of radioactive materials. Finally, it requires a vehicle design and operating environment that extends the margin of error so that when human errors occur, the opportunity to take a corrective action, can be made prior to an accident occurrence, thereby mitigating a potential accident or reducing the severity of the ensuing accident.

Policy recommendations can be formulated which are directed at emphasis areas identified during the conduct of this study. These emphasis areas include the following: (1) employee selection and hiring practices, (2) drug and alcohol use, (3) fatigue, (4) speeding and other moving violations, (5) operator training, (6) vehicle and environment factors, and (7) enforcement.

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1.0 INTRODUCTION

In response to growing public concern over the risk to public safety and the environment, increased attention has been focused on the transport of hazardous materials. In analyzing incidents and accidents that have occurred during transport operations, several recent studies have indicated that "human error" is a primary cause (see, for example, Office of Technology Assessment, 1986). However, a detailed examination of more specific contributing factors and the extent to which regulation and enforcement can be modified to decrease the likelihood of human error have not undergone extensive study.

Under the terms of the Nuclear Waste Policy Act (NWPA) of 1982, the U.S. Department of Energy's (DOE's) Office of Civilian Radioactive Waste Management (OCRWM) is responsible for transporting spent nuclear fuel and high-level radioactive waste from various generation and storage sites to a geologic repository. OCRWM has requested this study for the purpose of determining the extent of human factors effects on the safety of transporting radioactive waste materials. This project addresses three principal questions:

1. Are human factors likely to be a major cause of radioactive waste transport incidents/accidents?

2. What are human factors-related incident/accident characteristics and are they distinguishable from other causation factors?

3. How can these problems be addressed in terms of policies and programs directed at radioactive waste transport?

Although truck, rail and barge modes were considered in this analysis, a primary emphasis was placed on truck and rail operations, due to their more likely utilization in repository shipments of radioactive waste.

It is important to note that this study is envisioned as a scoping effort only, to establish whether there is a need for DOE to undertake a more formal program in the area of human factors in transportation, and if so, logical directions for that program to follow.

In addressing transport safety, a distinction is often made between the terms "incident" and "accident." An incident is defined as any unintentional release of a hazardous material during the transport process, including loading/unloading or temporary storage related to transportation. The term "accident" refers to a vehicular accident. Most hazardous materials transport incidents are not caused by vehicular accidents (e.g., loose fitting). For simplicity sake, the term "accident" will be used in this report to denote incidents and the term "vehicular accident" will be used when referring to crash circumstances.

1.1 DEFINING HUMAN FACTORS IN TRANSPORTATION SAFETY

In the transport of spent nuclear fuel or other complex technological systems, it is rather difficult to develop a consistent and universally accepted definition and identification of "human error." This is due in part to the purpose of the analysis, disciplinary perspective, and organizational or social objectives (Tuler, et al., 1988). In this study, a rather loose definition has been applied, namely "human error" is the behavior of a person transgressing the multidimensional bounds of acceptable performance (Sheridan, 1983). This approach is a rational one for considering transport operations, since the bounds of acceptable performance vary under normal and emergency conditions and include several criteria, such as technical and economic efficiency, system reliability and public safety.

The occurrence of a transport accident due to human error is part of a complex process that results in an accident experience. These events are typically comprised of multiple factors that collectively form a causal system. The system components include operating personnel, the vehicle, and the operating environment; economic and management factors can also be influential. The interrelationships of these factors are shown in Figure 1.

Normally, personnel, vehicle, and operating conditions contribute to an environment where, under most circumstances, adequate safety can be maintained. When one or more of these parameters is subjected to a situation that exceeds the safety margin, an accident may occur. If the normal margin of safety is reduced because of unsafe industry practices, the frequency and severity of accidents can be expected to increase.

Accident reports are often the basis for conducting safety analyses. However, these reports are limited in detail, and frequently the reported "cause" is the last and precipitating event in a chain of events. Thus, exploring accident information beyond a general level of detail is of critical importance.

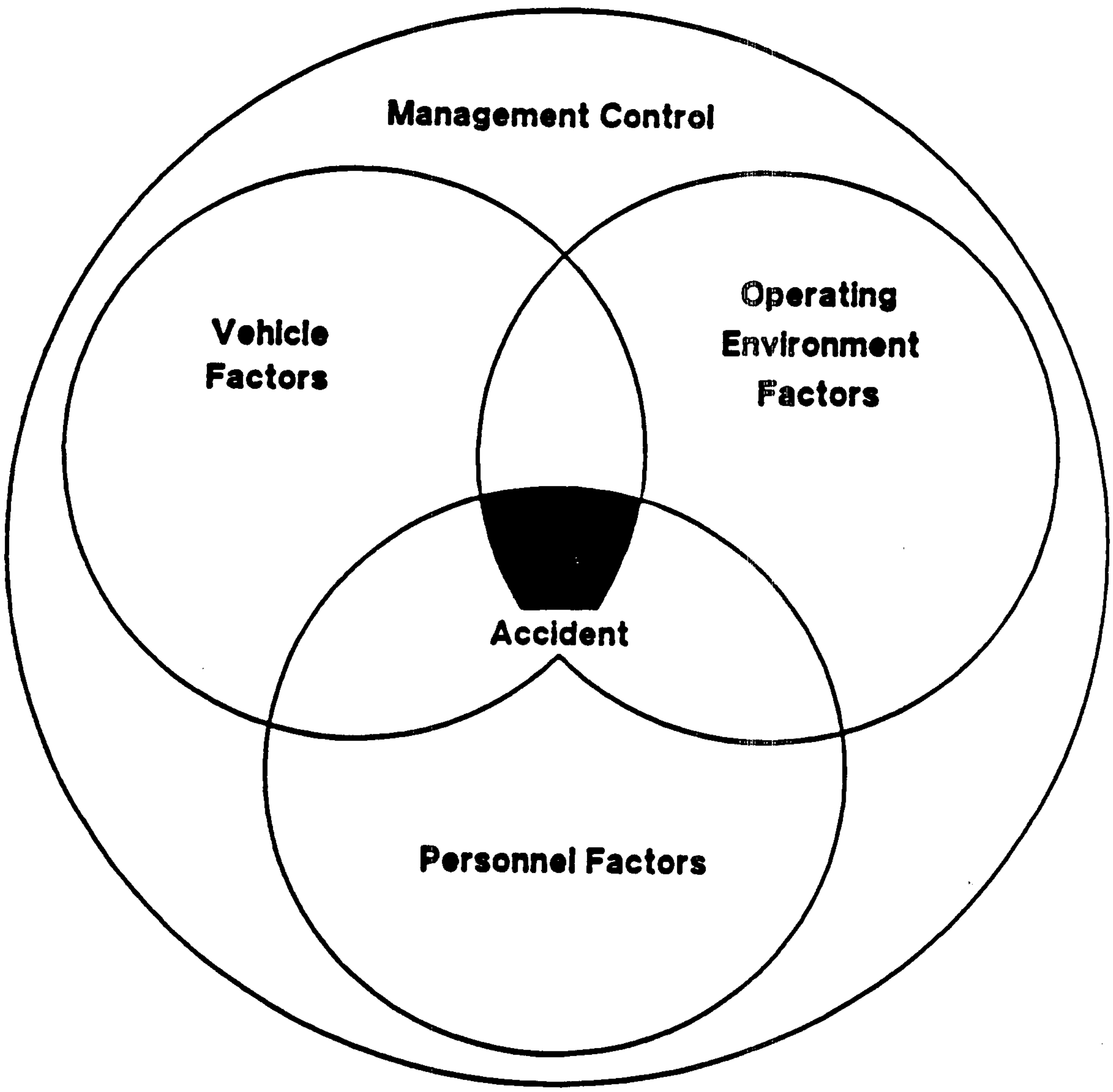
This applies, in particular, to human error, often cited as a primary accident causation factor. For example, in truck transport, when reporting vehicular accidents, police are required to attribute responsibility to one of the parties. Many enforcement officers are not familiar with the details of truck technology and overlook vehicular accident factors that the truck driver was unable to cope with because of limitations in the truck's handling capabilities. Thus, enforcement officers may attribute responsibility to the driver in more instances than warranted. For example, in California, vehicular accident reports associate driver error with over 90 percent of truck-at-fault accidents (California Highway Patrol, 1987). However, in the majority of cases, there are multiple causes, commonly involving driver error and defects in road design and the vehicle (Fructus, 1987).

1.2 HUMAN FACTORS AREAS IN THE NUCLEAR WASTE TRANSPORT PROCESS

The transportation of radioactive waste involves a number of stages of activity which depend on reliable human performance. In a broad sense, this encompasses transportation system design, implementation, operations, maintenance and accident recovery. This study focuses exclusively on transport operations, and more specifically on driving and loading/transfer operations. It excludes analysis of unloading accidents, as it is assumed that unloading operations at a monitored retrievable storage facility or geologic repository constitute a separate activity.

Particular emphasis is placed on the driving function, examining the relationship between human error and safety as it relates to the impairment of

Figure 1
Multiple Factor Accident Causation Model

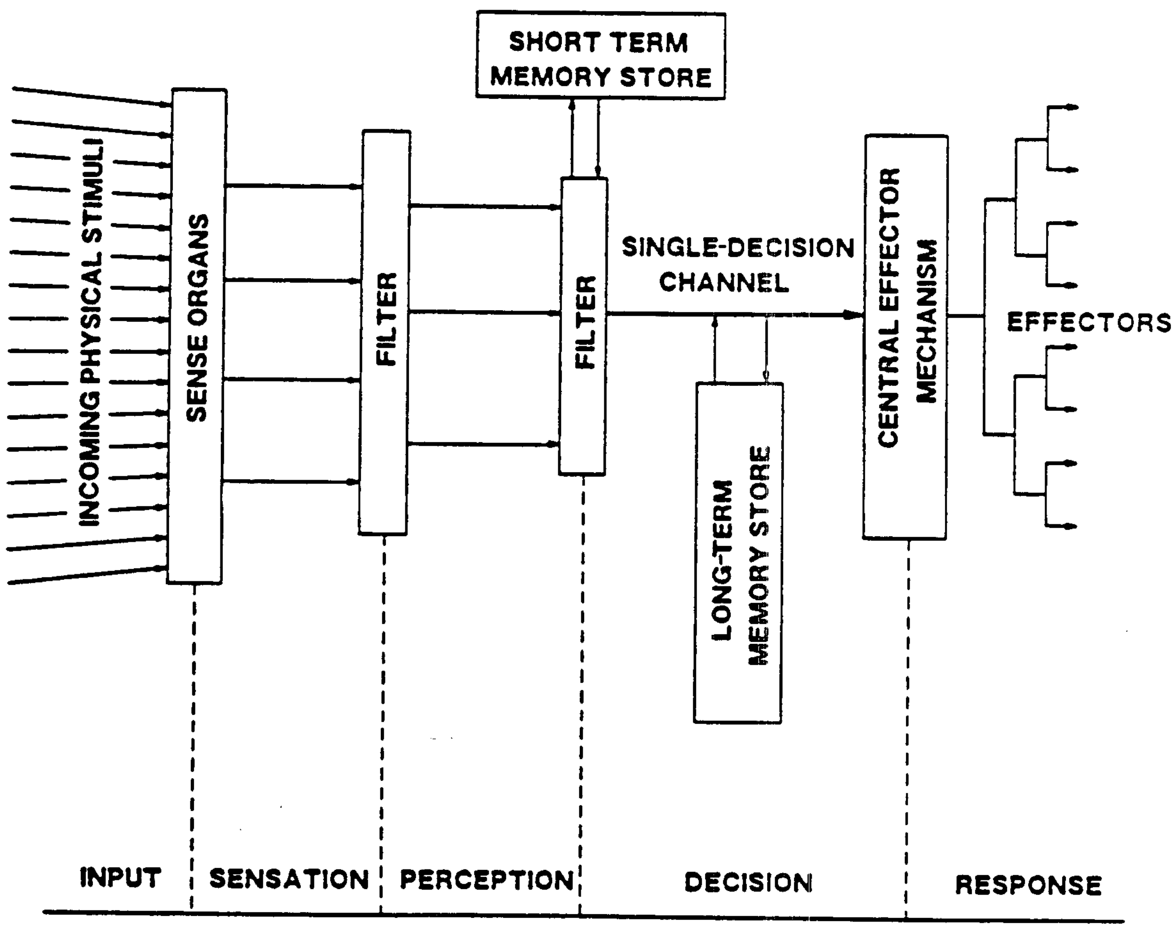


Source: Adapted from NHTSA, 1987

driver performance. As a preface to this discussion, it is useful to consider the processes at work when a human is placed in charge of an operating environment, such as behind the wheel of a commercial rig, where information must be continually processed and evasive actions taken. Figure 2 depicts a typical human information processing sequence. In essence, the driver is receiving new information, must recognize and evaluate it, reach a decision, and take a response action. Because of the continual change in the roadway environment and constraints on heavy-truck stopping capability and maneuverability, this suggests that a heavy-truck driver should be at the peak of alertness at all times, and have had sufficient driving experience to maintain an adequate margin of safety. Any impairment or behavioral characteristic which alters the ability to acknowledge information, perceive correctly, reach an informed decision and take a correspondingly safe driving action can seriously threaten safe driving performance.

An alert driver can execute the phases in Figure 2 in less than two seconds when confronted with an unexpected hazard in the roadway (Olson, 1984). However, given that even alert drivers have been shown to have only a single decision channel and therefore all information must be processed sequentially, the extent to which an impairment impacts the timeliness with which a potential conflict is recognized and an abatement action, if any, is taken, is also an important consideration (Allnutt, 1983).

Figure 2
Human Information Processing Sequence



Source: Allnutt, 1983

2.0 INFORMATION SOURCES FOR HUMAN FACTORS ANALYSIS

An essential component of safety measurement and evaluation is a complete and accurate database that contains relevant accident statistics. The identification of factors contributing to accident causation and severity is central to the establishment of priorities for improvements and corrective actions.

2.1 AVAILABILITY AND QUALITY OF ACCIDENT DATABASES

From a safety analysis perspective, one would like to have an abundance of information on radioactive waste transport accidents, such that an empirical analysis could be undertaken whose results would be directly applicable. However, historically there have been relatively few radioactive waste accidents (and shipments), and there is not sufficient sample size from which to conduct rigorous statistical analysis on this basis.

The next most desirable option would be to restrict the analysis focus to all hazardous materials accidents whose chemical qualities, packaging and release characteristics most resemble those found in the transport of nuclear waste. This effort was pursued in the course of this study in an attempt to reach a broad understanding of human error as a contributing factor.

More specific information on the characteristics of the accident is generally not available until one investigates vehicular accident reporting systems which focus on all freight cargo. These databases often include a hazardous materials flag, indicating when an accident involves a hazardous material, but the material itself is not usually specified. Thus, some segmentation of the data can take place as it relates to the study in question.

This approach results in the development of a hierarchy of relevant accident information as shown in Figure 3. An obvious tradeoff emerges in that if detailed human factors analysis is desired, dependence on more general vehicular accident data is necessary, and implications on radioactive waste transport must be made by inference.

A full discourse on hazardous materials transportation accident information systems (including reporting criteria) appears in Appendix A, and is summarized in Table 1. A review of these sources was conducted as part of this study, resulting in the identification of the following databases which were deemed potentially relevant to the project objectives. Each of these databases is described briefly below.

2.1.1 Hazardous Materials Information System (HMIS)

Maintained by the U.S. Department of Transportation (DOT) in the Office of Hazardous Materials Transport (OHMT), this database became the centralized Federal system for uniform accident data in 1971. As prescribed in the 49 CFR regulations, carriers are required to report any unintentional release of a hazardous material during transportation, with the exception of consumer commodities which present only a limited hazard during transportation,

Figure 3
Hierarchy of Relevant Accident Information by Mode

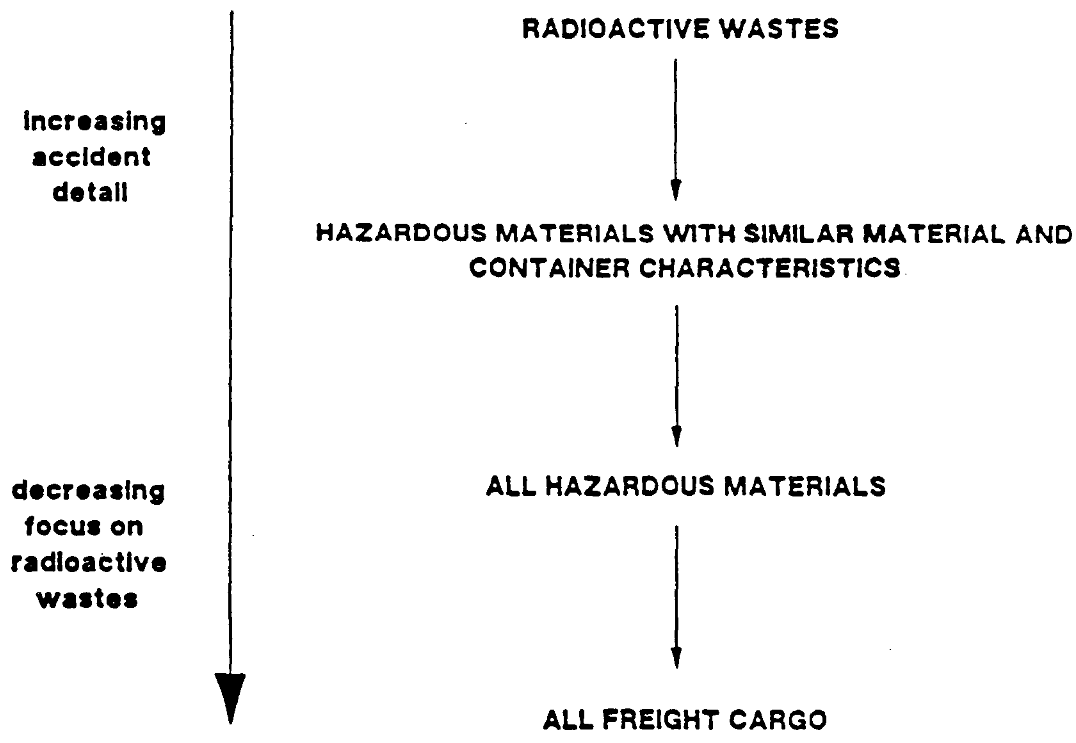


Table 1. Potential Accident Databases

Database	Kept by	Years	Modes	Vehicular Accidents	Accidents	Exclusive hazardous materials focus	Exclusive transport focus
Hazardous Materials Information System	DOT, Office of Hazardous Materials Transportation, Research and Special Programs Administration	1971 to present	All	Yes	Yes	Yes	Yes
U.S. Dept. of Energy Data Base	Sandia National Labs	1979 to present	All	Yes	Yes	Yes	Yes
National Accident Sampling System	National Highway Traffic Safety Administration	1979 (Hazardous materials flags added in 1983)	Highway	Yes	No	No	Yes
Fatal Accident Reporting System	National Highway Traffic Safety Administration	1976 (Hazardous materials flags added in 1983)	Highway	Yes	No	No	Yes
Truck Accident File	DOT, Bureau of Motor Carrier Safety, Federal Highway Administration	1973 to present	Highway	Yes	No	No	Yes
State Accident Files	State Transportation Agencies	Varying	Highway	Yes	No	No	Yes
Railroad Accident File	Federal Railroad Administration	1973 to present	Rail	Yes	No	No	Yes
Commercial Vessel Casualty File	U.S. Coast Guard	1963 to present	Marine	Yes	No	No	Yes
National Transportation Safety Board File	National Transportation Safety Board	--	All	Yes	No	No	Yes
National Response Center	U.S. Coast Guard	--	All	Yes	Yes	Yes	No
Pollution Incident Reporting System	U.S. Coast Guard	1971 to 1985	All	Yes	Yes	Yes	No

electric storage batteries, and certain paints and related materials (General Services Administration, 1984).

In many respects, the HMIS database serves as the most relevant database for conducting hazardous materials transport safety analysis. It represents the only system devoted exclusively to hazardous materials transport accidents, and as such, it includes a number of descriptors that can be used to examine issues in packaging, labeling, accident causation and public safety that might not otherwise be possible.

Although spill reporting is a regulatory requirement, in practice it is handled on a voluntary basis, quite possibly because of the small size of the DOT enforcement staff and the relatively minor penalties for non-reporting. It has been estimated that up to and perhaps more than 30-40% of reportable accidents are never reported (OTA, 1986). Other problems emanate from: (1) shippers and freight forwarders not being required to submit accident reports, (2) reports are not required by OHMT for accidents involving bulk marine shipments, and (3) DOT has elected not to regulate carriers involved only in intrastate transportation.

If the deficiencies in the HMIS database are accepted as stated, the total volume of hazardous materials transport accidents is clearly understated. However, for the purposes of deriving distributions of events, causes and consequences, and for some multi-modal comparative analyses, as is the intention of this study, the HMIS database may still be representative.

2.1.2 Nuclear Incident Database

DOE maintains a database of all radioactive transportation accidents, based on the HMIS file and information from the Nuclear Regulatory Commission on the loss of control of radioactives. The database consists of approximately 70% HMIS records and 30% Nuclear Regulatory Commission records.

In the past, this database has been maintained, on-line, at Sandia Labs. Recently, responsibility for database management shifted to Oak Ridge National Laboratory, and then was moved back to Sandia again. Because of the sudden change in management responsibility of this database, requests for data were not being handled during the time that this study was carried out.

2.1.3 National Accident Sampling System (NASS)

The National Highway Traffic Safety Administration (NHTSA) maintains vehicular accident data on police reported accidents. The data is typically collected by each State under contractual agreement with NHTSA.

The file of reported vehicular accidents is called the National Accident Sampling System (NASS). The vehicular accidents investigated are a probability sample of all police-reported accidents in the United States. The data collection for a NASS-selected vehicular accident is very involved, and includes follow-up investigation of the characteristics of the accident, driver, occupants and vehicle. Although the specific commodity being carried is not described for truck accidents, sufficient information exists to track accidents which involved hazardous cargo (NHTSA, 1981a).

Because of the accident detail contained in the NASS reports, this is seen as a primary database for analyzing human factors involving truck in-transit vehicular accidents.

2.1.4 Fatal Accident Reporting System (FARS)

Those vehicular accidents which result in loss of human life are also classified separately by NHTSA in the Fatal Accident Reporting System (FARS). FARS is not a national sample; rather, it includes all fatal traffic accidents that are reported in the United States (NHTSA, 1981b). Other than this distinction, however, the information collected parallels the NASS data structure as described previously.

In the context of this effort, since FARS represents only the most severe of vehicular accidents, analyses of FARS data was considered as a useful basis for comparison to NASS findings in assessing the relationship between human factors and accident severity.

2.1.5 Commercial Vessel Casualty File (CVCF)

The Commercial Vessel Casualty File (CVCF) is maintained by the U.S. Coast Guard. It includes both domestic and foreign vessel accidents occurring in U.S. waters, and domestic vessel accidents occurring in foreign waters. Fields in each record include vessel characteristics, event, cause, fatalities/injuries and monetary damage. Each accident record also contains specific vessel codes which indicate whether hazardous cargo was involved (U.S. Coast Guard, 1984).

Unfortunately, the level of detail present in the CVCF accident record for human factors analyses is not of the caliber available in the NASS and FARS databases. Consequently, use of this database was restricted in this study to deriving general estimates of the frequency of vessel accidents attributable to human factors.

2.1.6 FRA Accident File

The Federal Railroad Administration (FRA) maintains its own accident database from information generated by railroads, inspectors and OHMT. The database includes some general information on likely human error-related accidents and potential causal factors. The FRA Accident File was also restricted in its use to providing aggregate estimates of accidents due to human factors.

2.2 ANALYSIS METHODOLOGY

As noted in the previous discussion, although several databases have been identified that are potentially relevant to the study of human factors effects on the safety of transporting radioactive waste materials, none have been designed for the specific purpose of investigating human factors. Consequently, certain aspects of each of the databases are pertinent to this study, although in most cases their use is restricted to general estimates of the magnitude of the human factors problem, and fall short of providing input to the development of more specific programs and policies.

The desire to focus on commodities and containers which are similar to those being used or under consideration for the transport of radioactive waste materials, coupled with an interest in isolating loading and in-transit accidents, necessitates extensive use of the HMIS database. There is simply no other historical accident database that can provide these insights, albeit that the HMIS database suffers from some data collection problems as described earlier.

The basis for identifying human factors issues at a level of detail that prompts discussion of explicit programs and policies appears to be restricted to truck in-transit activities. The NASS and FARS databases contain considerable accident information from which to delve into specific human factors questions, such as driver behavior, vehicle performance and operating conditions. Unfortunately, a similar resource is not available for evaluating the rail and barge industries, as the FRA and CVCF files are not designed to address these considerations at an appropriate level of detail.

The subsequent result of the data search was to refine the focus of this initial human factors study to a general assessment of the scale of the human factors problem that could be expected in the radioactive waste transport industry, with an identification of more specific areas for DOE policy consideration that apply to truck transport. Of course, there may be several areas where policies directed at truck transport could be transferable to the rail and barge industries.

Concurrent with efforts to identify and analyze relevant accident data, an extensive literature review was undertaken to search for previous studies related to human factors in transportation that might be relevant to the safe transport of radioactive wastes. As in the case of the database review, it became readily apparent that considerably more information is available on human factors in truck transport than for rail and barge operations. Findings from the literature review are discussed in Chapter 4.

3.0 DATA ANALYSIS

Using the HMIS database as the primary information source, analyses were undertaken to address the question of whether human factors might be a likely cause of nuclear waste transport accidents, and whether human factors accident characteristics are distinguishable from accidents caused by other factors.

Although the HMIS database dates back to 1971, a decision was made to exclude pre-1980 accidents from the analysis so that containers in the database might be more reflective of container technology in place today while maintaining adequate sample size.*

The HMIS database classifies the commodity shipped by name as well as by hazard class. A review of the hazard class descriptions revealed that several classes contained materials whose chemical qualities and packaging had little in common with radioactive waste shipments. For example, inclusion of corrosive materials would not be particularly relevant to the issue under study consideration. Because the radioactives accident sample size by itself was too small, the following group of four hazard classes were ultimately selected as being most representative of radioactive waste movements, and the analysis was subsequently restricted to an examination of accidents involving these materials:

1. Radioactives
2. Combustible Liquids
3. Flammable Liquids
4. Flammable Compressed Gases

In the remainder of this document, this group is referred to as the "proxy hazard classes."

Each accident record in the HMIS database also includes a detailed container specification. Even within the proxy hazard classes, some containers did not have design characteristics with any similarities to those under consideration for radioactive waste transport. Furthermore, the distinctions between rail and truck container specifications, as well as between radioactives and other hazardous cargo containers are sufficiently different that they may warrant separate consideration. Consequently, within the proxy hazard classes, the following four mutually exclusive container categories were defined for analysis purposes:

1. Rail Tank Cars
2. Radioactive Materials Containers
3. Bulk Highway Shipments
4. Other Containers

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*1980 was defined as the cutoff date based on discussions with Battelle staff engineers.

A methodology for isolating loading and in-transit accidents for the proxy hazard classes was also developed. Loading/unloading accidents were separated from in-transit accidents on the basis of detailed accident cause codes which were identified as being either more pertinent to loading or in-transit operations, respectively. Unloading accidents were subsequently removed from the database by searching and retaining only loading/unloading accidents that occurred at the shipment origin.

Table 2 shows the number of recorded accidents in the HMIS database for each analysis cell. It is rather evident from observing this table that the number of reported radioactive material accidents is quite small, particularly loading accidents. This also confirms the need to include the proxy hazard classes for analysis purposes.

Table 2. HMIS Sample Size by Container Class and General Cause for Proxy Hazard Classes, 1980-87

	HUMAN ERROR		OTHER THAN HUMAN ERROR	
	Loading	In-Transit	Loading	In-Transit
Rail Tank Cars	18	1,250	16	1,745
Radioactive Material Containers	5	8	1	29
Bulk Highway Containers	540	626	201	2,513
Other	2,165	6,672	126	10,659

Source: HMIS data, 1980-87

3.1 HUMAN ERROR AS A GENERAL ACCIDENT CAUSE

The HMIS accident record includes both a general cause code and more specific accident causation factors. Each recorded accident is classified according to one of the following four general causes:

1. Human Error
2. Container Failure
3. Vehicle Accident
4. Other

This designation is made by the carrier when filing the accident report and is therefore subject to their interpretation. Furthermore, there may be some mis-classified accidents, since the categories are not mutually exclusive. For example, in the case where a vehicular accident is due to human error, the general cause could be attributed to one of two categories. With these caveats in mind, the results reported below should be considered approximations of the scale of the human factors problem that might face the radioactive waste transport program.

Figure 4 depicts the frequency with which human error is reported as the general cause of loading accidents for the proxy hazard classes, segmented by container class. A couple of observations can be made from reviewing the results. In an absolute sense, human error is listed as the general accident cause the majority of the time, irrespective of which container category is considered. In a relative sense, human error is more likely to be cited as the general cause for container failure in other than the groups considered most similar to radioactive waste container transport. On the other hand, human error is cited in over 80% of specific radioactive material container failures, although one must keep in mind the small sample size from which this statistic is derived.

Similar general cause information for in-transit accidents appears in Figure 5. Here, human error is not cited as frequently as the primary accident cause, although it remains prominent and continues to dominate other accident factors in several instances.

At a mode-specific level, human error as a primary accident cause was investigated for rail and marine transport, using the FRA Accident File and CVCF, respectively. In both instances, hazardous materials shipments were segmented from other shipments to provide for a comparative basis. Figure 6 shows that human factors is the second leading cause of rail accidents both for hazardous and non-hazardous shipments. It is interesting to note that human factors are cited more frequently for non-hazardous shipments, suggesting the possibility that some additional care is exercised over the shipment of dangerous cargo as it relates to personnel involvement.

Figure 7 presents a slightly different picture for marine transport, particularly if one combines "crew at fault" with "other personnel/vessel." The U.S. Coast Guard treats these separately in order to determine which crew is at fault during collisions, etc. It is interesting to note that when personnel are blamed, more often than not the other vessel is considered at fault, certainly a typical response when interviewing people in multiple-vehicle traffic accidents. Nevertheless, it appears that human

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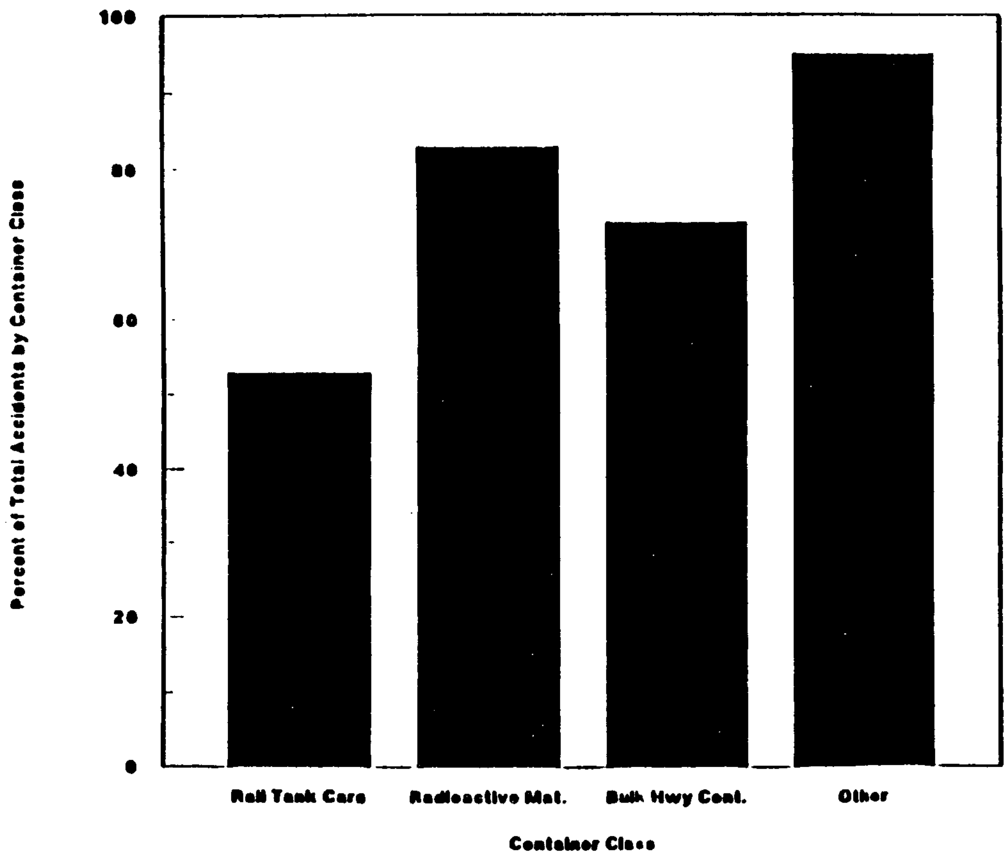
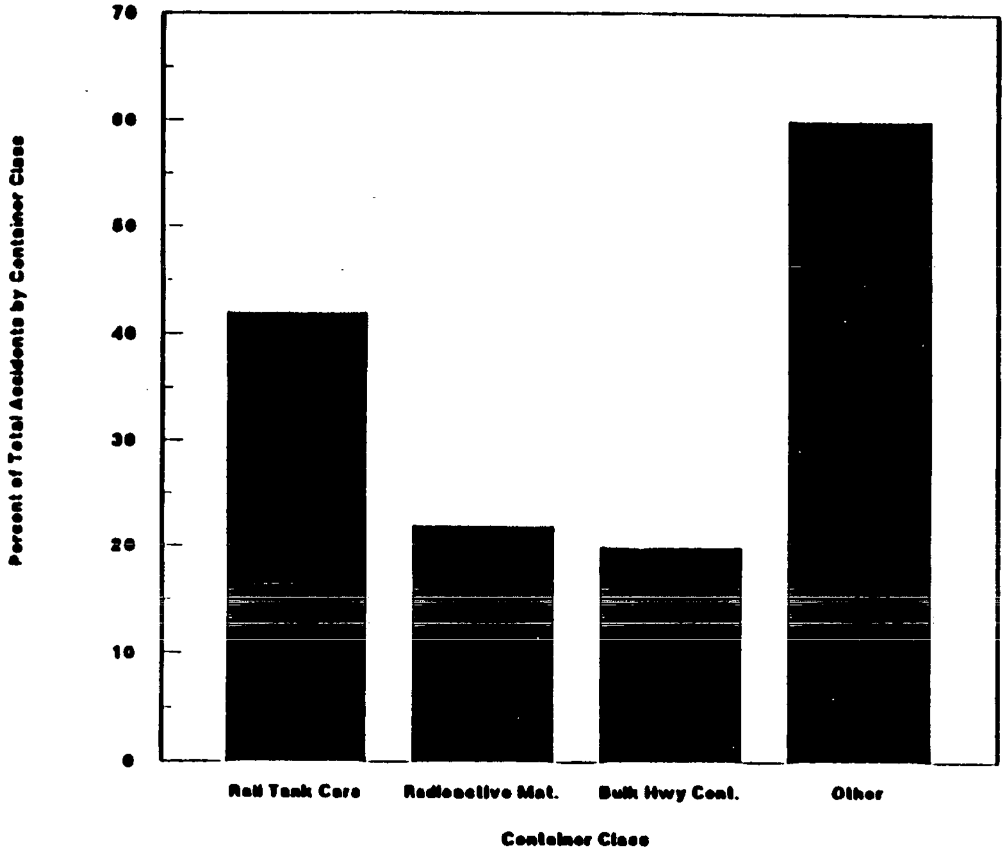
Figure 4
Human Error as Loading Accident Cause by Container Class for Proxy Hazard Classes



Source: HMIS database, 1980-87

Figure 5
Human Error as In-Transit Accident Cause by Container Class for Proxy Hazard Classes



Source: HMIS database, 1986-87

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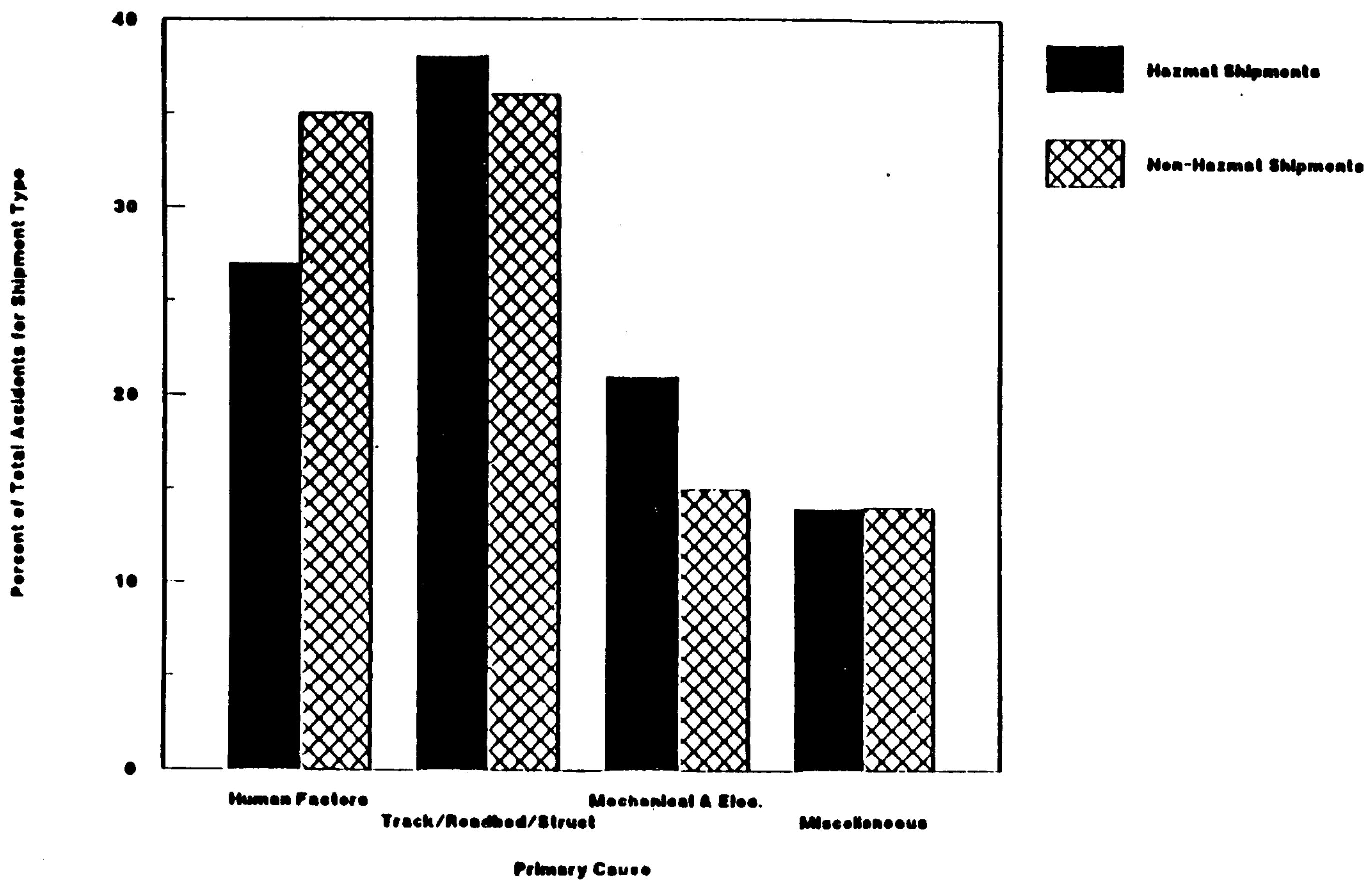
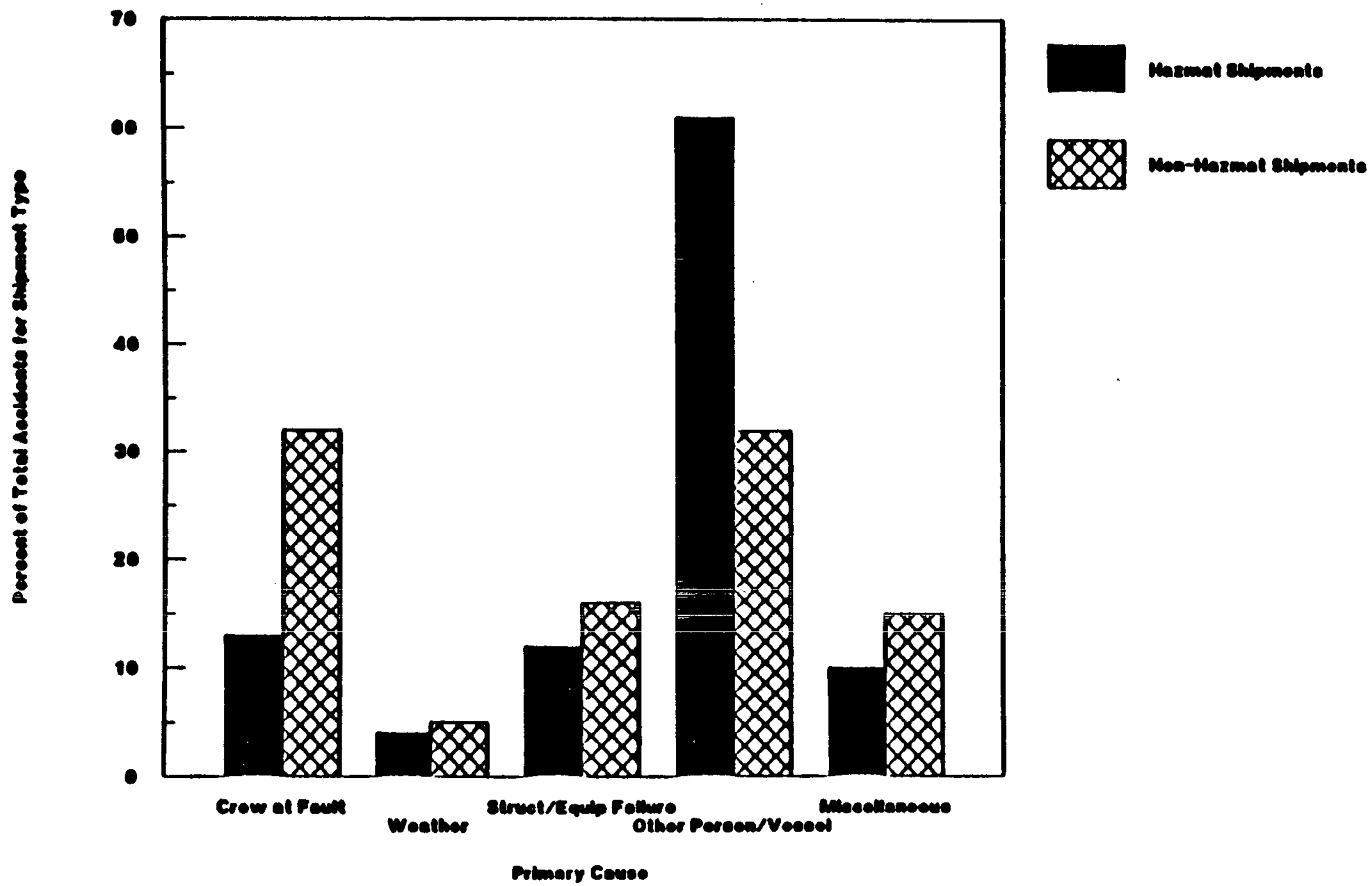
Figure 6
Primary Cause of Rail Accidents



Source: FRA, 1980-86

Figure 7
Primary Cause of Marine Freight Transport Accidents



Source: Commercial Vessel Casualty File, 1972-86

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factors are the dominant cause for marine freight transport accidents, although the distinction between hazardous and non-hazardous shipments is less clear because of the way in which the accident information has been recorded.

3.2 MORE SPECIFIC ACCIDENT CHARACTERISTICS INVOLVING HUMAN ERROR

In an attempt to focus more specifically on the human function which failed in accidents where human error was cited, analyses were conducted on the primary reason for container failure using the HMIS database. Figures 8-13 present container failure causes for accidents involving proxy hazard classes, segmented by container categories and by whether the accident occurred during loading or while in-transit. The results in each figure are reported separately for accidents where human factors were cited as the general cause and for all other accidents.*

Several observations can be made from reviewing this material. First, for container types which most closely resemble nuclear waste transport shipments, human error problems during the loading process focus on failure to secure fittings, valves and other container closures; improper blocking; and dropped during handling. Secondly, human error problems for container types which most resemble nuclear waste transport shipments during in-transit operations include releases from loose fittings, valves and closures; internal pressure; and external puncture, presumably due to contact between the container (tank car) and another object in crash scenarios. The high frequency of reported human failure to secure fittings, valves and closures as the cause of in-transit accidents clearly relates to the loading process. Internal pressure suggests the need to carefully monitor temperature and pressure changes during transport. Puncture to the container during in-transit accidents suggests the need for proper securing, shielding and design protection of the casks in preparation for in-transit operations.

The reason for the rather large discrepancy between human factors problems for other shipments, both loading and in-transit, and those which most resemble radioactive waste shipments, is that many of the other commodities are sent in smaller packages, of which several may be included in a single shipment. Consequently, there is a greater opportunity for a package to be dropped during handling or damaged by other freight, perhaps due to improper blocking.

3.3 ACCIDENT CONSEQUENCE

In addition to identifying the frequency of occurrence of human factors-related accidents, it is also important to examine the severity of such accidents. The average property damage per loading accident for proxy hazard classes is shown in Figure 14, segmented by container type and general

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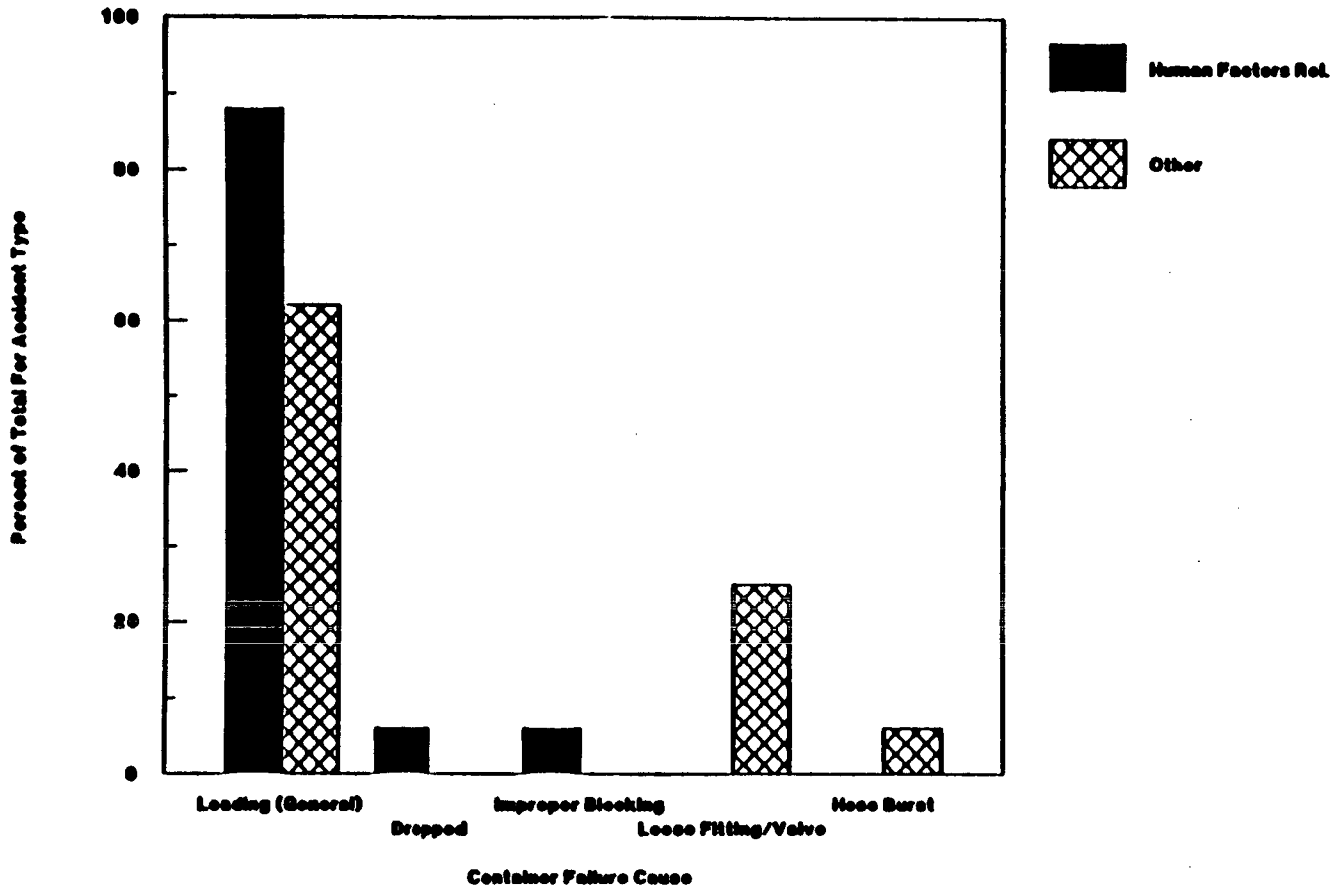
* Figures do not appear for radioactive material containers due to the small sample sizes involved.

Figure 8
Container Failure Cause for Rail Tank Car Loading Accidents Involving Proxy Hazard Classes



Source: HMIS database, 1980-87

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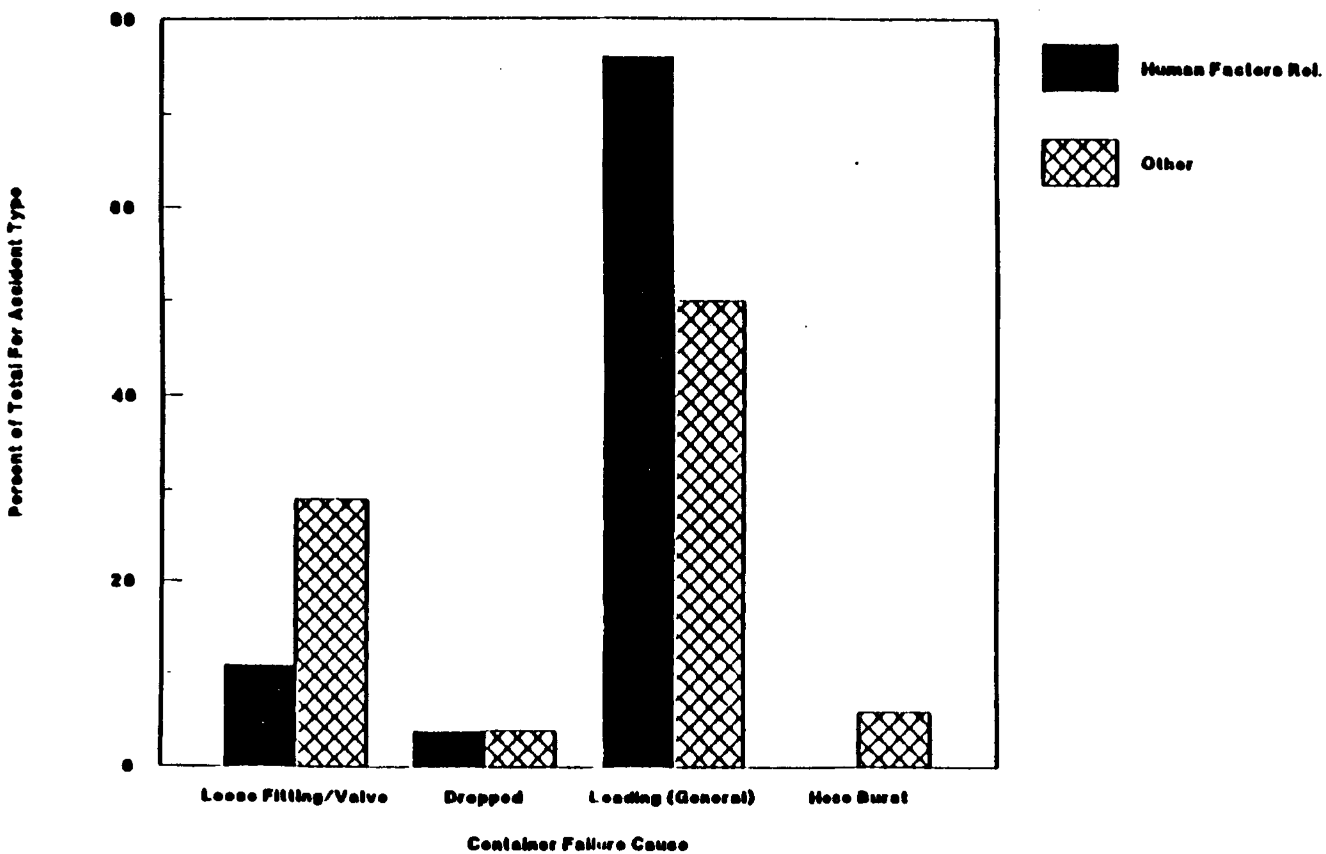
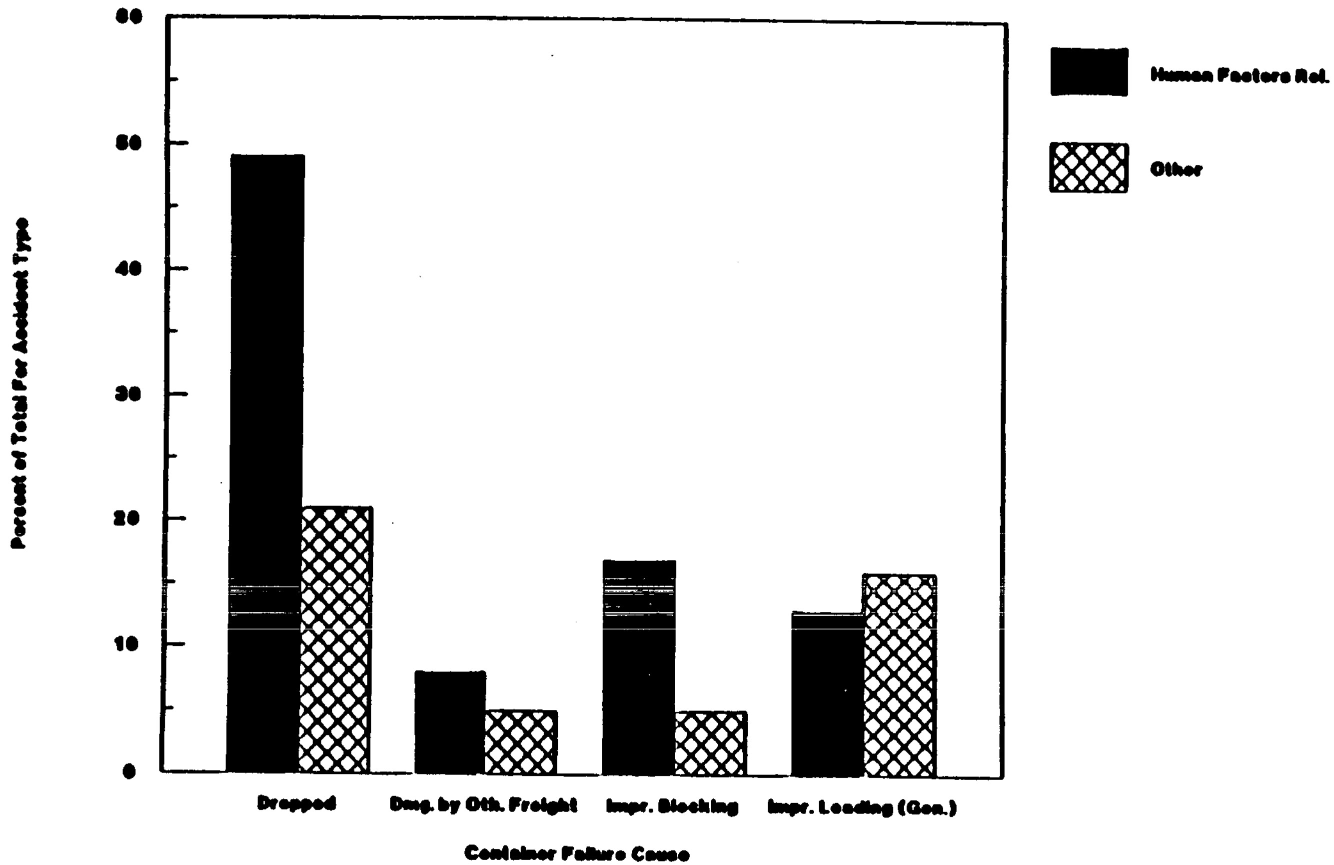
Figure 9
Container Failure Cause for Bulk Highway Loading Accidents Involving Proxy Hazard Classes



Source: HMIS database, 1980-87

Figure 10
Container Failure Cause for Other Loading Accidents Involving Proxy Hazard Classes



Source: HMIS database, 1980-87

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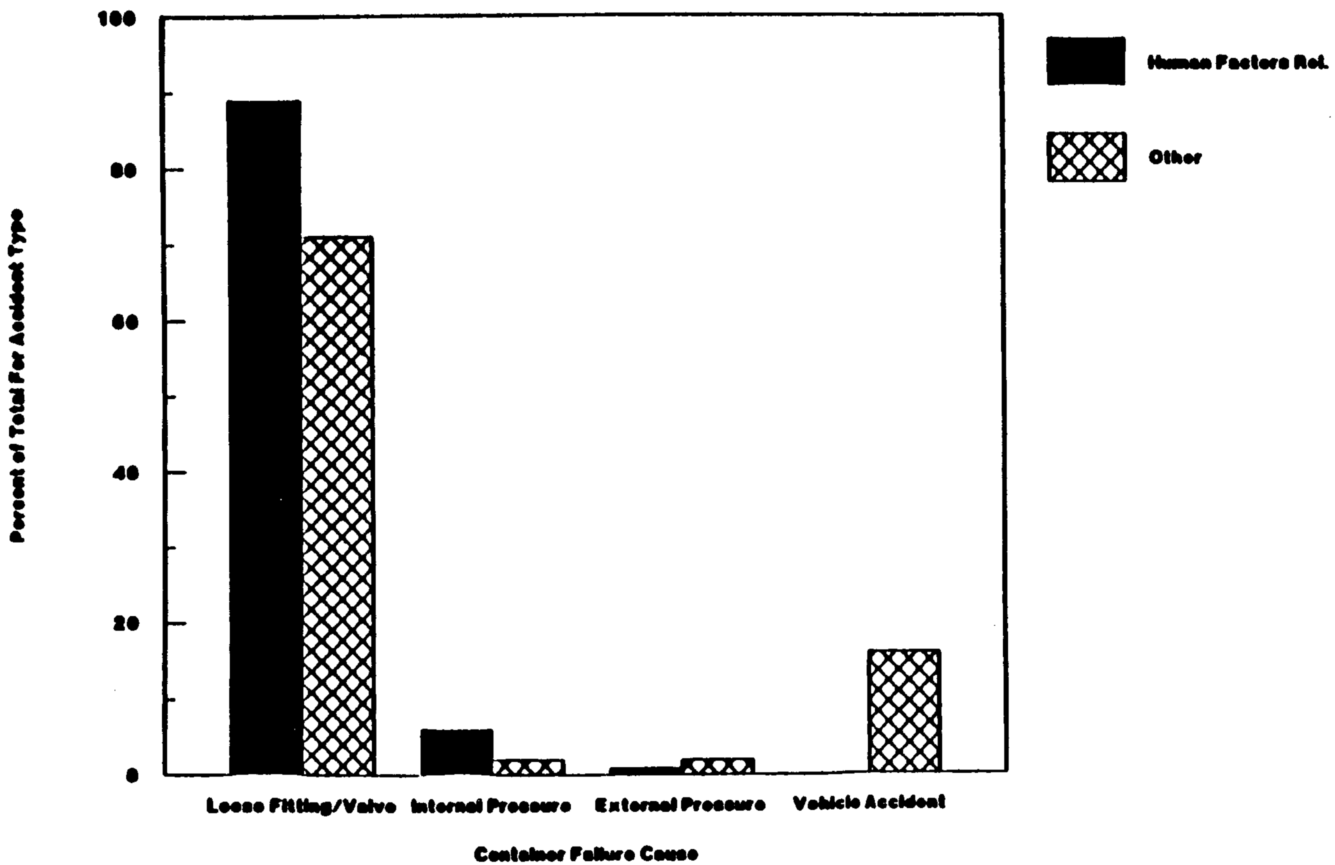
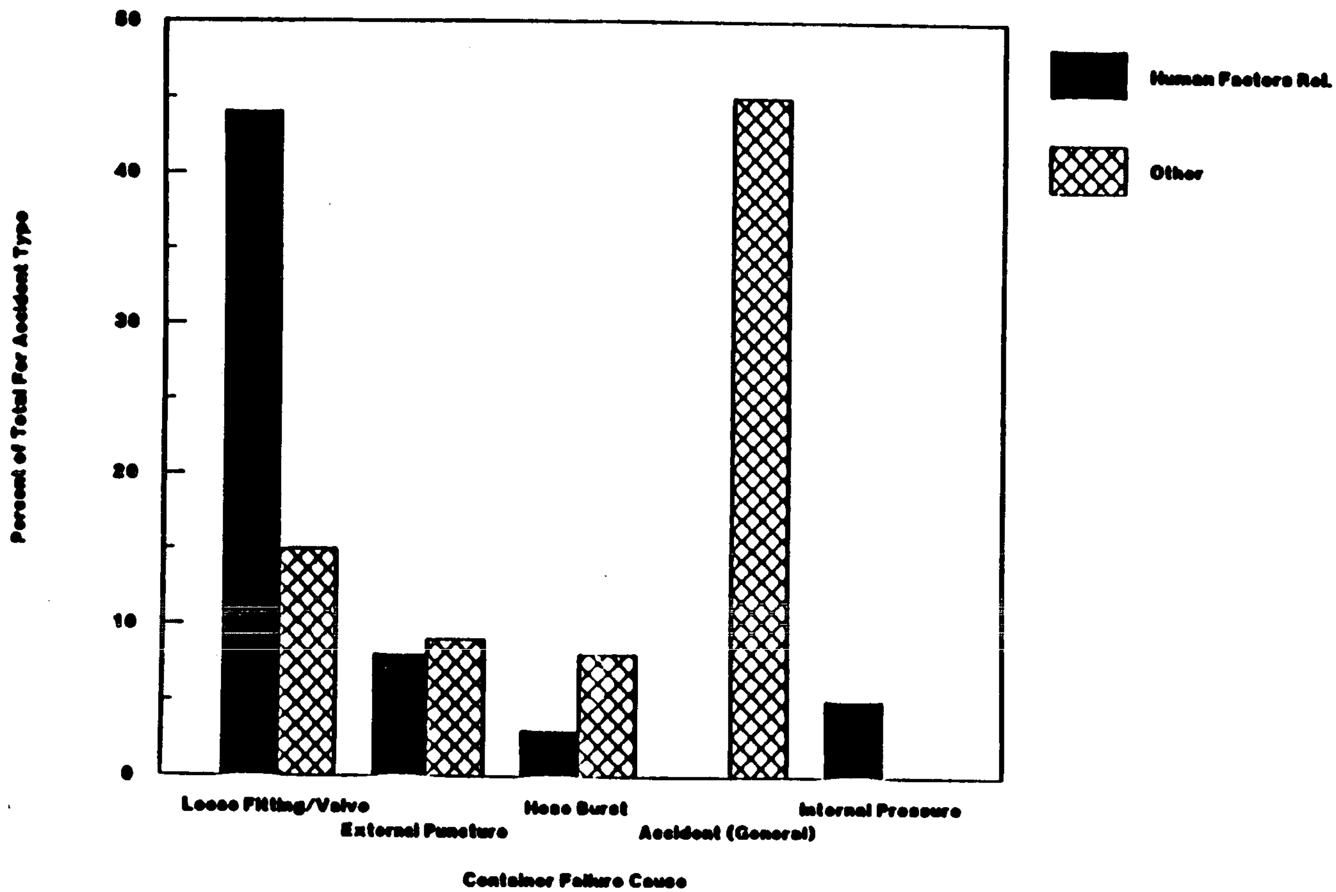
Figure 11
Container Failure Cause for Rail Tank Car In-Transit Accidents Involving Proxy Hazard Classes



Source: HMIS database, 1986-87

Figure 12
Container Failure Cause for Bulk Highway In-Transit Accidents Involving Proxy Hazard Classes



Source: HMIS database, 1980-87

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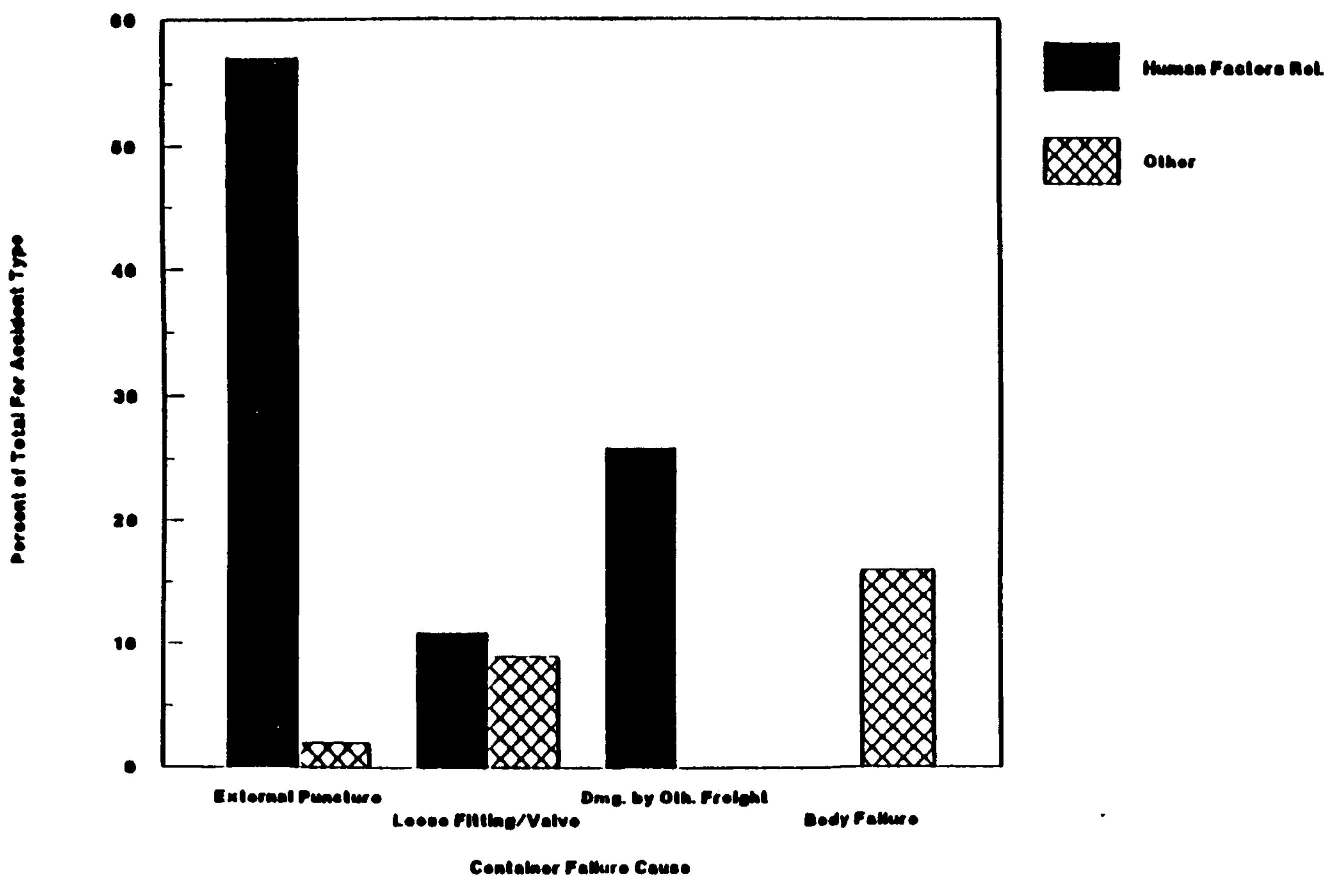
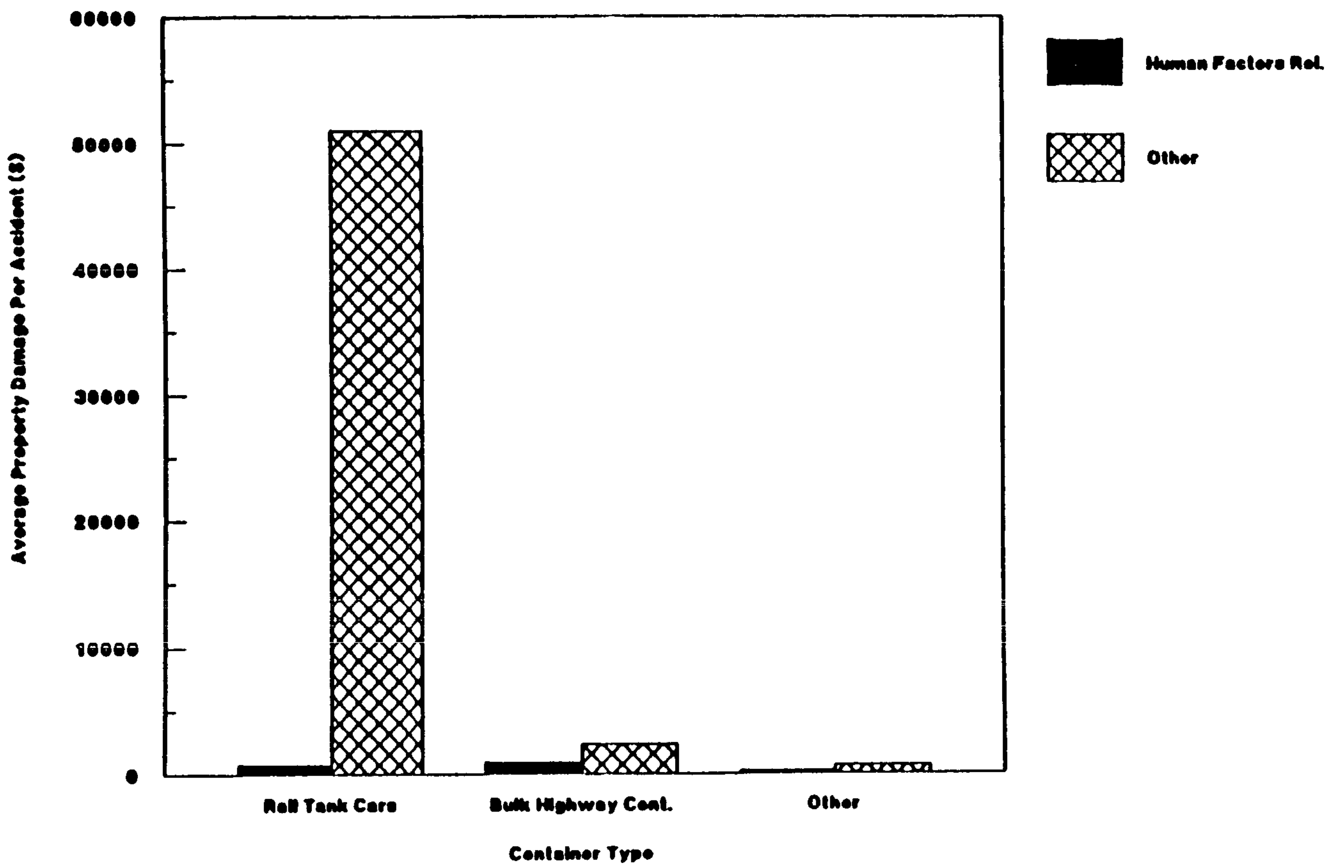
Figure 13
Container Failure Cause for Other In-Transit Accidents Involving Proxy Hazard Classes



Source: HMIS database, 1980-87

Figure 14
Loading Accident Consequences by Container Class for Proxy Hazard Classes



Source: HMIS database, 1980-87

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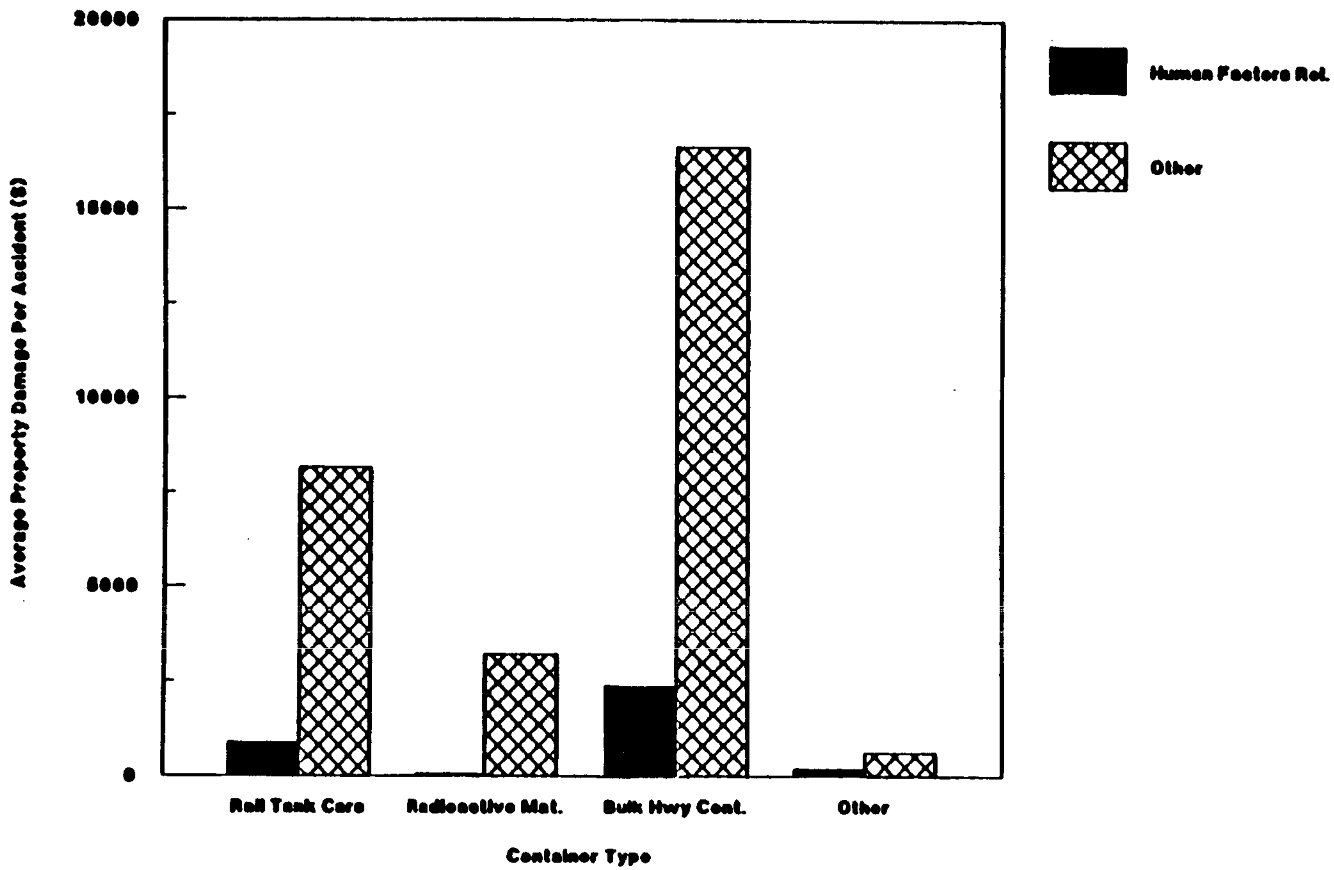
accident cause.* It appears that the accident severity for human-factors related loading accidents is considerably lower than for accidents caused by other factors, regardless of the container type under consideration. This same relationship holds for in-transit accidents, as noted in Figure 15.

* Similar analyses were also conducted on fatalities and injuries. The results were highly correlated with those for property damage.

Figure 15
In-Transit Accident Consequences by Container Class for Proxy Hazard Classes



Source: HMIS database, 1980-87

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4.0 SIGNIFICANT OR EMERGING HUMAN FACTORS PROBLEMS

On the basis of the previous analyses, it is apparent that human error is a leading cause of accidents involving the transport of materials in containers that resemble radioactive waste shipments. It can be inferred from these results that human factors effects on radioactive waste transport operations are likely to be significant to the point where a more formal DOE human factors research program and program policies should be established. While one can argue over the apparent lower accident severity associated with human factors-related accidents, both loading and in-transit, the high frequency of such events coupled with the public perception of a nuclear accident independent of severity, suggests that the occurrence of these accidents should be kept to an absolute minimum.

As noted earlier, most of the available accident databases are not capable of providing accident characteristics at a level that corresponds to the detailed identification of significant or emerging human factors problems. The exception, the NASS and FARS databases, can provide some insights for the trucking industry. The extent to which additional information might be available from prior research studies to support this effort prompted the undertaking of an archival search for relevant literature.

4.1 LITERATURE REVIEW

The literature review process was conducted with the aid of a computerized search through the Transportation Research Information Service (TRIS) file. From a list of several hundred potentially relevant references, a review of abstracts resulted in the identification of a small subset of these documents which were deemed relevant to the project scope. Most of this material was obtained for use in this study.

A couple of observations are appropriate here regarding the human factors in transportation literature. First, there appears to be considerably more information and prior attention focused on human factors issues in the trucking industry relative to other modes, particularly in the past decade. Very little activity focusing on rail operations has occurred since the late 1970's, and focus on marine transport has been consistently sparse.

Concerning subject matter, most of the recent attention has focused on fatigue, training, and drug and alcohol abuse. Some of this is couched in extensive discussions of the environment in which drivers must operate, including present-day economic and managerial pressures. There has also been some attention focused on the cab environment, including the effects on occupational health (and attentiveness) from prolonged exposure to noise, vibration and other elements.

The availability of NASS (and FARS) data, coupled with rather extensive outside literature on human factors in the trucking industry, led to a decision to fully develop an understanding of potential problems that might plague the truck transport of nuclear waste materials. This is addressed in Section 4.2. Although much more restrictive in nature, similar discussions for rail and marine transport are provided in Sections 4.3 and 4.4, respectively.

4.2 HUMAN FACTORS IN TRUCK SAFETY

This section discusses what is known about human factors in truck safety based on NASS (and FARS) database analysis, and a review of pertinent literature. It includes a discussion of significant and emerging driver behavior problems as well as the development of policy options to address these concerns. Vehicle, roadway and economic factors are also described briefly, to the extent that they interact with the human factors area.

4.2.1 Driver Behavior

Driver behavior is generally recognized to be a function of both the characteristics of the driver and external factors affecting his attitude and performance. Driver characteristics can include experience, prior training, age (attitude), physical condition (fatigue, intoxication, other debilitations), and psychological state. External factors may include regulatory oversight (e.g., licensing, traffic enforcement) and the type of supervision exercised by the carrier.

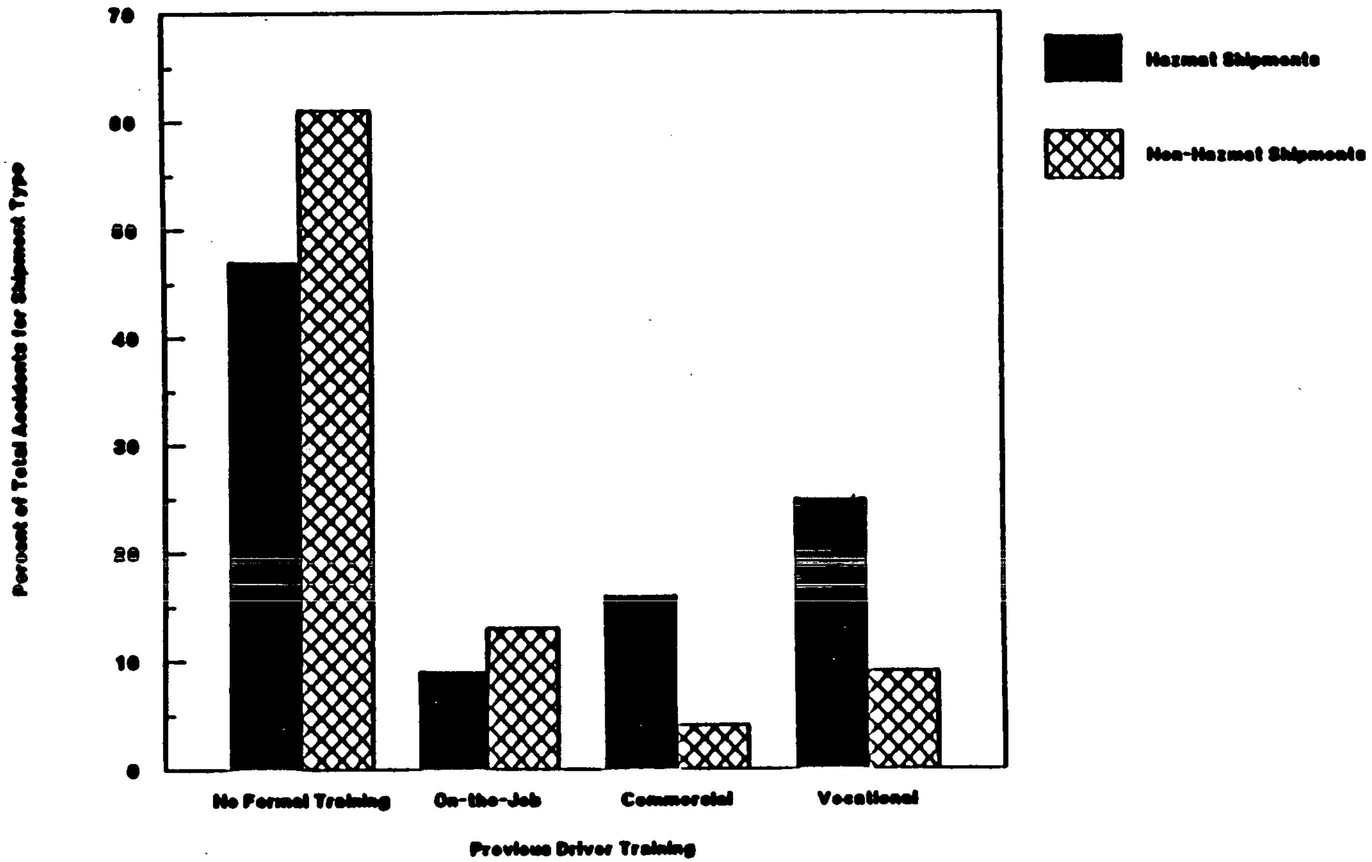
4.2.1.1 Driver Training

Results from an analysis of 5 years of the NASS data (1981-85) indicate that several driver-related factors warrant further investigation. Figure 16 shows the level of prior driver training received by heavy-truck drivers involved in accidents, segmented by hazardous and non-hazardous cargo shipments. Indeed, the majority of accident-involved heavy-truck drivers never received any formal training, commercial vehicle or otherwise, before operating a rig. Relatively speaking, drivers involved in accidents carrying hazardous cargo were more likely to have had formal training, although their absolute percentage of untrained drivers signals a serious deficiency.

In a survey of the general population of heavy-truck drivers, 23% reported receiving driver training prior to becoming a professional driver (Regular Common Carrier Conference, 1987). However, of those drivers who reported regularly handling hazardous materials, 87% had not received any formal training on the specifics of hauling dangerous cargo (Wyckoff, 1979). Surprisingly, though, drivers with formal training, on the average, reported driving faster, misrepresenting their log books more frequently, exceeding the 10-hour shift limit more regularly, and having more accidents per 100,000 miles when compared to drivers without formal training. Although these findings may appear counter-intuitive, it is important to note that drivers with formal training are predominantly younger drivers whose safety performance may be impacted by age and experience as discussed in Section 4.2.1.5.

The lack of training is also associated with accident severity. According to analyses of NASS (1981-85) and FARS data (1983), 58 percent of heavy-truck drivers involved in accidents did not receive prior training, as compared to 74 percent of truck drivers involved in fatal accidents. Both the preponderance of untrained drivers and the overinvolvement of untrained drivers in fatal accidents warrant attention.

Figure 16
Driver Education of Accident-Involved Heavy-Truck Drivers



Source: NASS, 1981-86

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4.2.1.2 On-the-Road Performance

Where driver-related factors have been specified on the accident report form for hazardous cargo accidents,* the most frequently cited occurrences include driving too fast for conditions, poor lane changes, and disobeying traffic signals. A more detailed investigation of the role of human factors in truck accidents in Finland also points to failures in controlling the vehicle, in estimating the traffic situation, and in perception as the principal causes when human error is cited as the primary factor. Driver attitude and the physical or mental state of the driver emerge as key accident characteristics when human error is given as a secondary cause (Stocker, 1987). Similar findings were reported in Oregon in an analysis of heavy-truck at-fault collisions - the principal causes were improper maneuvers, speed too fast for conditions, and driver fatigue and inattention (Oregon Public Utility Commissioner, 1985).

The frequencies of driver error for the truck driver and for the driver of the other vehicle in truck accidents appear in Table 3, which shows the contrast between the operating performance of each party in crash circumstances in Washington State. Areas of poor performance by the truck driver include inattention, exceeding reasonable speed, following too closely, and improper turning maneuvers.

Through the Federal Motor Carrier Safety Assistance Program (MCSAP), several States have also found excessive speed to be the most frequent human factor involving accident causation. For example, Maryland and Massachusetts as well as Oregon cite speeding as the most common accident causation factor.

The association between speeding and accident causation deserves further consideration in the context of the recent increase in the speed limit to 65 mph on many rural interstates. A 1987 survey of truck drivers' opinions carried out in Florida for the Regular Common Carrier Conference addressed driving habits of long-haul truck drivers under the new posted speed limits. Table 4 shows the results reported from interviews with 1,762 truck drivers. Furthermore, seventeen percent of the drivers interviewed indicated that they are being asked to make faster deliveries now than before the 65 mph speed limit was approved. This apparent push toward higher truck speeds and faster expected delivery times, even on roadways whose posted limits did not change, is disturbing.

Higher posted speed limits also increase the variation in speed of any vehicle from the average speed of all traffic. Greater variation in speed leads to increased accident likelihood by providing more conflict situations, such as passing maneuvers and braking (Solomon, 1964).

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* In the National Accident Sampling System (1981-85), driver-related factors in hazardous cargo accidents are specified approximately 30% of the time.

Table 3. Contributing Circumstances to State of Washington Crashes in 1984

Causal Factor	Truck or Truck Driver in Truck Accidents		Other Vehicle or Driver in Truck Accidents	
	Number	Percent	Number	Percent
DRIVER ERRORS				
Inattention	1,128	(22)	659	(17)
Failure to yield right of way	513	(10)	445	(11)
Exceeding reasonable speed	670	(13)	348	(9)
Alcohol	56	(1)	141	(4)
Disregard stop sign/signal	58	(1)	100	(3)
Following too closely	277	(5)	111	(3)
Exceeding stated speed	55	(1)	56	(1)
Over center line	120	(2)	106	(3)
Improper passing	71	(1)	126	(3)
Improper turn	271	(5)	91	(2)
Apparently asleep	62	(1)	20	(.5)
Drugs	1	(0)	5	(.1)
Failed to signal	22	(.4)	22	(.6)
Disregard warning sign/signal	25	(.5)	10	(.3)
Improper parking location	46	(.9)	21	(.5)
Improper signal	10	(.2)	7	(.2)
No lights/failed to dim	8	(.2)	5	(.1)
DEFICIENT EQUIPMENT	343	(7)	64	(2)
OTHER VIOLATIONS	606	(12)	240	(6)
NO VIOLATION	1,674	(33)	1,627	(42)
TOTAL ACCIDENTS	5,051	(100)	3,901	(100)

Note: In some accidents there were no contributing circumstances noted, while in others there were several noted.

Source: NHTSA, based on data from the Washington Utilities and Transportation Commission.

Table 4. Interviews About Truck Cruising Speeds of Long-Haul Drivers

Since Approval of the 65 mph Speed Limit, Have Truck Cruising Speeds Increased, Decreased, or Stayed the Same on Roadways Where:

	Increased	Same	Decreased
55 mph is still posted	26%	69%	6%
65 mph is now posted	30%	68%	2%

Source: Regular Common Carrier Conference, 1987.

4.2.1.3 Previous Driving History

Evidence exists that heavy-truck drivers involved in accidents have a history of previous safety violations, even those carrying hazardous cargo shipments. As noted in Figure 17, in many instances a truck driver involved in a NASS-recorded accident had received previous citations, particularly for speeding and other moving violations, and had been involved in previous accidents. The national estimates from NASS data (1981-85) show that 30 percent or more of truck drivers involved in hazardous cargo accidents had at least one prior speeding conviction in the previous 3 years and at least one additional moving violation. One in every four accident-involved drivers carrying hazardous cargo had at least one accident prior to the recorded one. As in the case of driver training, although accident-involved drivers of hazardous cargo fared slightly better than the accident-involved truck driver population as a whole, it is apparent that poor driving records are scattered among a considerable number of truck drivers.

4.2.1.4 Drugs and Alcohol

Alcohol impairment studies based on police reports often show a low percentage of intoxicated truck drivers. However, studies using blood tests and small samples have shown that as many as 33% of fatally injured truck drivers had positive BAC's (Ranney, et al., 1984). The preliminary results of a recent special heavy-truck accident investigation being conducted by the National Transportation Safety Board (NTSB) indicate that over 17 percent of completed cases involved a driver impaired by either alcohol, drugs, or both. In the majority of accidents, the driver was either not tested or refused testing, which may explain the discrepancies between these results and those derived from police reports. Moreover, all of the impaired-driver cases in the NHTSA study involved some type of improper driver judgement that resulted in the accident.

Additional evidence of a growing drug and alcohol problem comes from a 1986 survey sponsored by the Regular Common Carrier Conference of 1,319 long-haul, tractor-trailer truck drivers operating out of Florida (Beilock, 1987). In this survey, drivers were asked their perception of fellow drivers' usage of drugs and alcohol. The "average" respondent felt that 36 percent of fellow drivers sometimes drive under the influence of drugs. Perceived use of alcohol was lower; 18 percent of all drivers were described as sometimes driving under the influence of alcohol.

Further indication that a drug problem may exist among truck drivers is presented in an Australian study of heavy-truck safety (Lees, 1987). A survey by the National Road Freight Industry Inquiry found that 66 percent of long-distance drivers use drugs to stay alert.

Alcohol involvement and accident consequence are strongly correlated. Figure 18 shows the severity of injuries as a function of whether heavy-truck driver drinking was involved. Regarding accident types, single-vehicle, road departure accidents, often at night, were found to be predominant among drinking truck drivers (Ranney, et al., 1984). The correlation between truck driver drinking and accident severity suggests that a drinking driver may either fail to react or react more slowly and less definitively in a situation with accident potential, heightening the intensity of a subsequent crash.

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* blood-alcohol concentration

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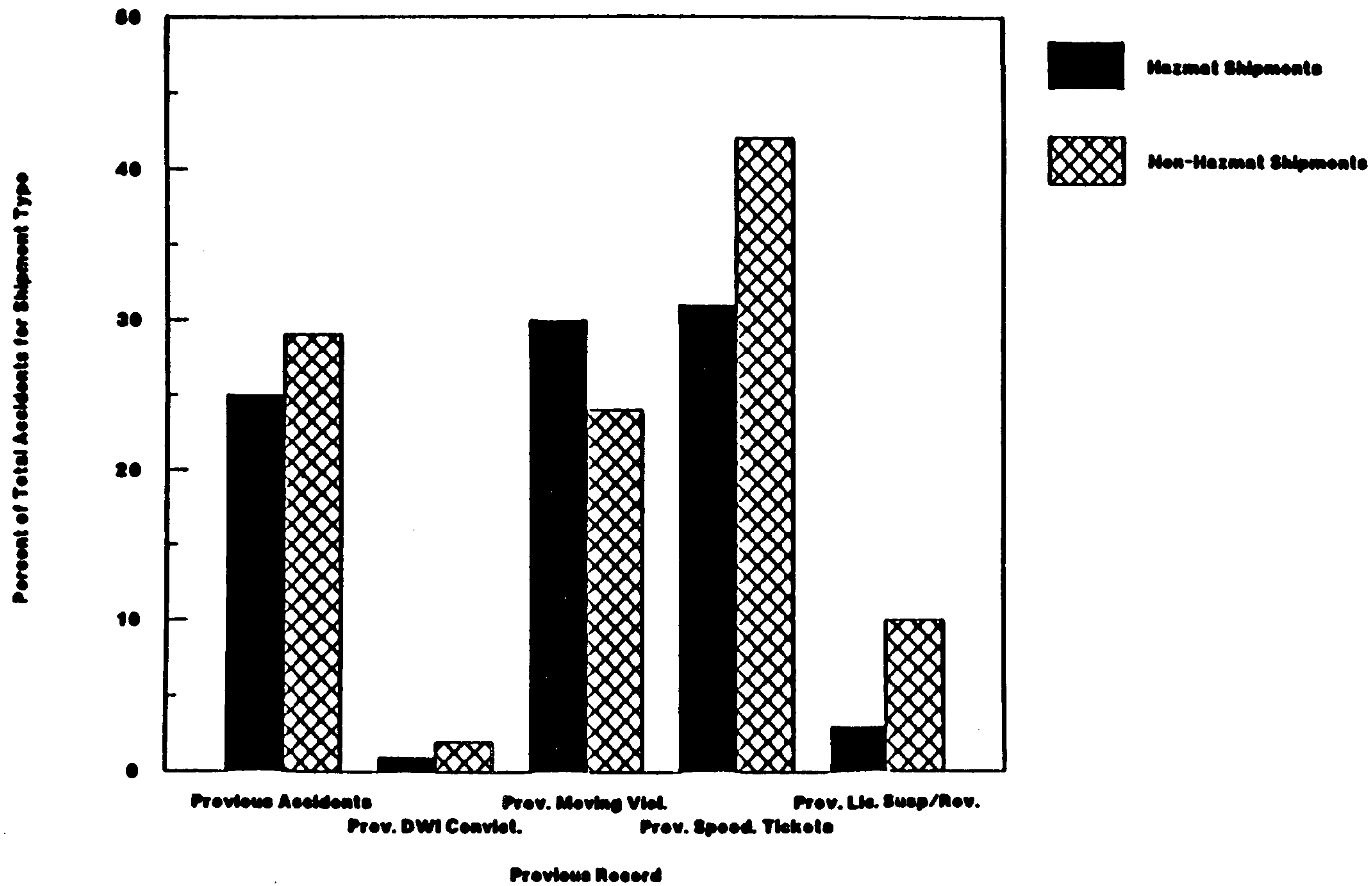
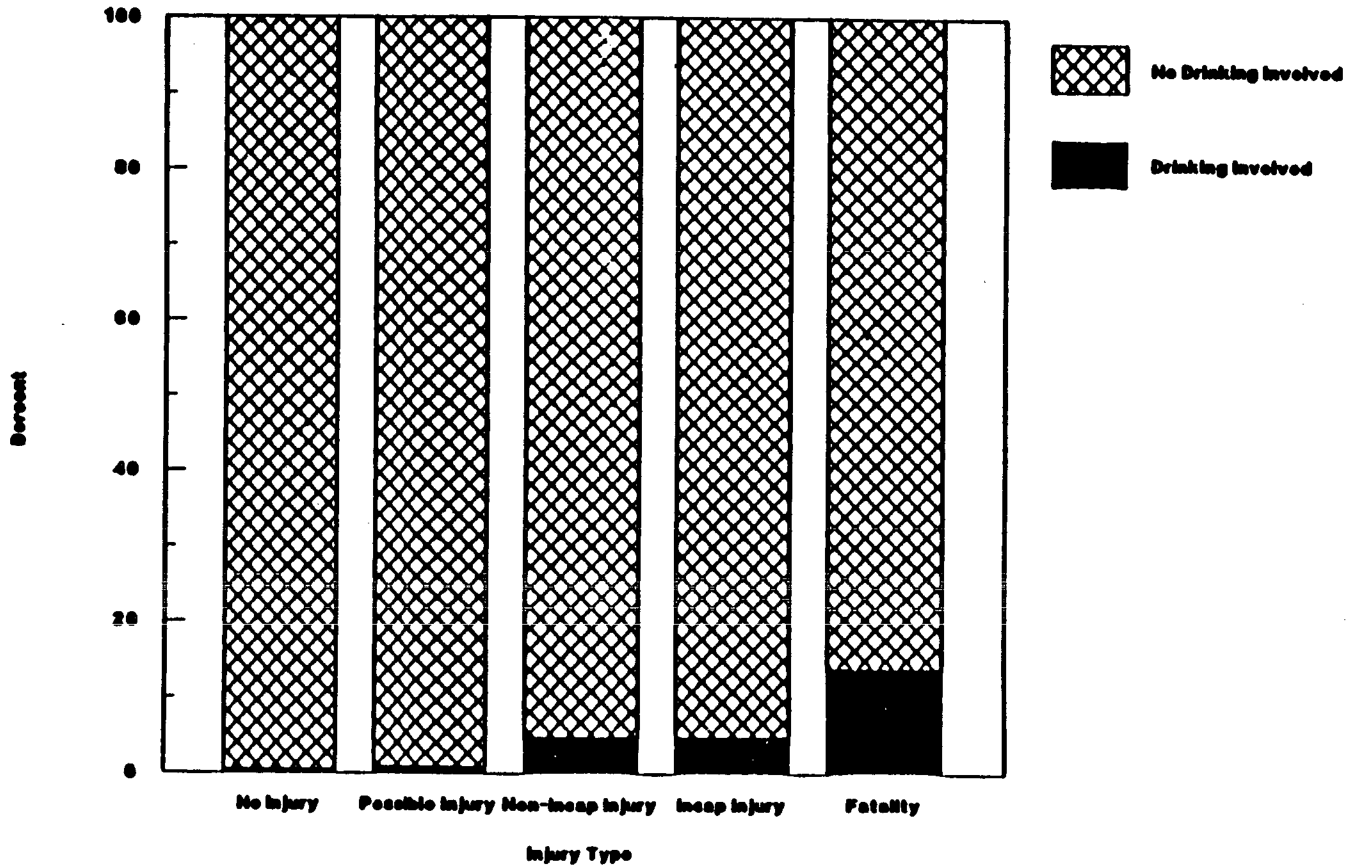
Figure 17
Previous Driving Records for Accident-Involved Heavy-Truck Drivers



Source: NASS data, 1981-85

Figure 18
Effect of Heavy-Truck Driver Drinking Involvement on Injury Severity



Source: NASS data, 1981-85

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4.2.1.5 Age and Experience

Young and inexperienced drivers are the truck driver groups with the highest risk of accident (Jones and Stein, 1988; Sanders, 1980; Green, et al., 1980). It has been reported that drivers under 25 years of age are six times more likely than other heavy-truck drivers to be involved in an accident (Hackman, et al., 1978). Other studies indicate that drivers with less than 1 year of experience constitute 1 percent of the carrier workforce, yet account for 3 percent of the accidents (Jovanis, 1987).

According to one study, by their own estimates, younger truck drivers complained more often about monotony, boredom and loneliness. They also were reported to be more than twice as likely to regularly experience fatigue at the wheel in comparison to the heavy-truck driver population as a whole, and more likely to drive after drinking or using marijuana. A greater adherence to safety rules was, as expected, also correlated with increased age of the driver.

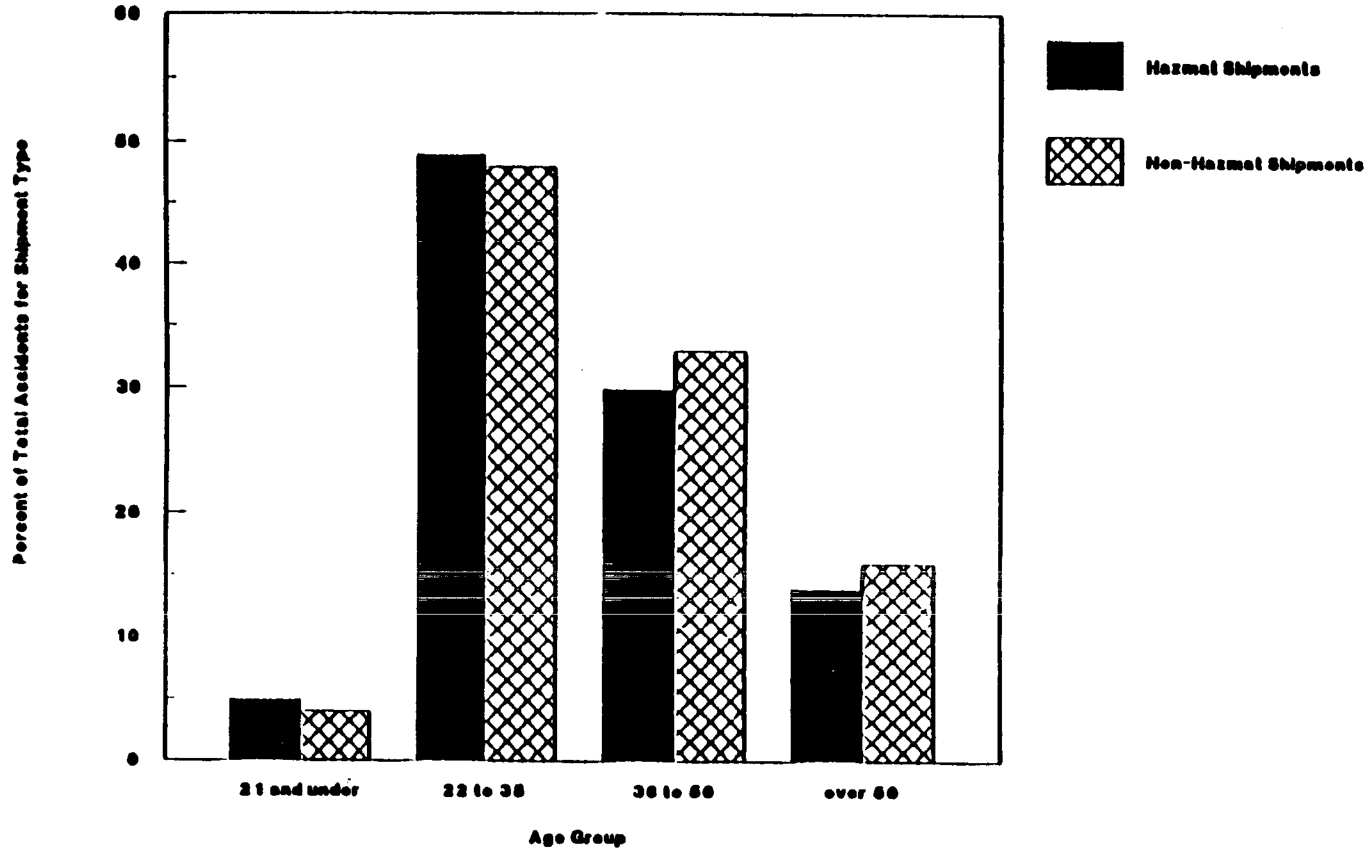
Figure 19 shows the age of accident-involved drivers, segmented by hazardous and non-hazardous cargo, based on an analysis of NASS data. There appears to be no indication that older drivers are associated with more dangerous cargo movements. Therefore, the increased "risk" of younger drivers does not appear to be reflected in driver assignments involving hazardous shipments.

4.2.1.6 Fatigue

As shown in Figure 20, a European truck safety study found that drivers traveling several days in a row, as a group, spend more time working than other drivers over a 24-hour period (Hamelin, 1987). Although it cannot be proven conclusively from observing this figure, it is conceivable that these drivers work as frequently as other drivers during the day, yet remain on duty, predominantly driving, after normal business hours. Such drivers either spend daytime hours involved in driving or loading/unloading, preceded or followed by additional driving. This pattern can lead to both sudden fatigue, due to temporary irregularities of the sleep cycle, and accumulated fatigue, due to long working hours. The fatigue, in turn, reduces the drivers' sensorial and motor capacities.

Using a survey of truck driving patterns to measure exposure, accident experience and exposure were also compared to ascertain periods of high accident risk (Hamelin, 1987). Figure 21 shows that accident involvement rates generally increase throughout the day, reaching a daylight peak at lunch time, and then growing more dramatically at the end of the afternoon, into the evening, and late at night. Figure 22 shows that accident involvement rates are relatively high for short work spans, then diminish, and increase again for shifts lasting more than 12 hours. A risk peak in the first hour of any shift has been reported by other heavy-truck safety research conducted on circadian rhythms (Jovanis, 1987), as well as a higher incidents of reported dozing among drivers who admit regularly to exceeding a 10-hour driving shift (Wyckoff, 1979).

Figure 19
Driver Age for Accident-Involved Heavy-Truck Drivers



Source: NASS, 1981-85

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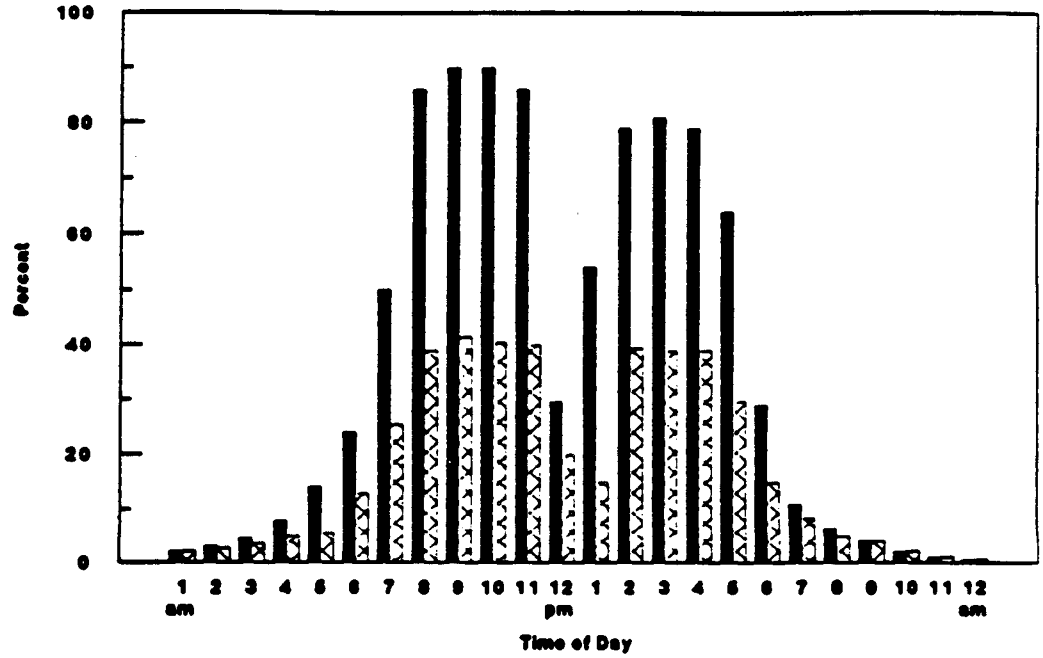
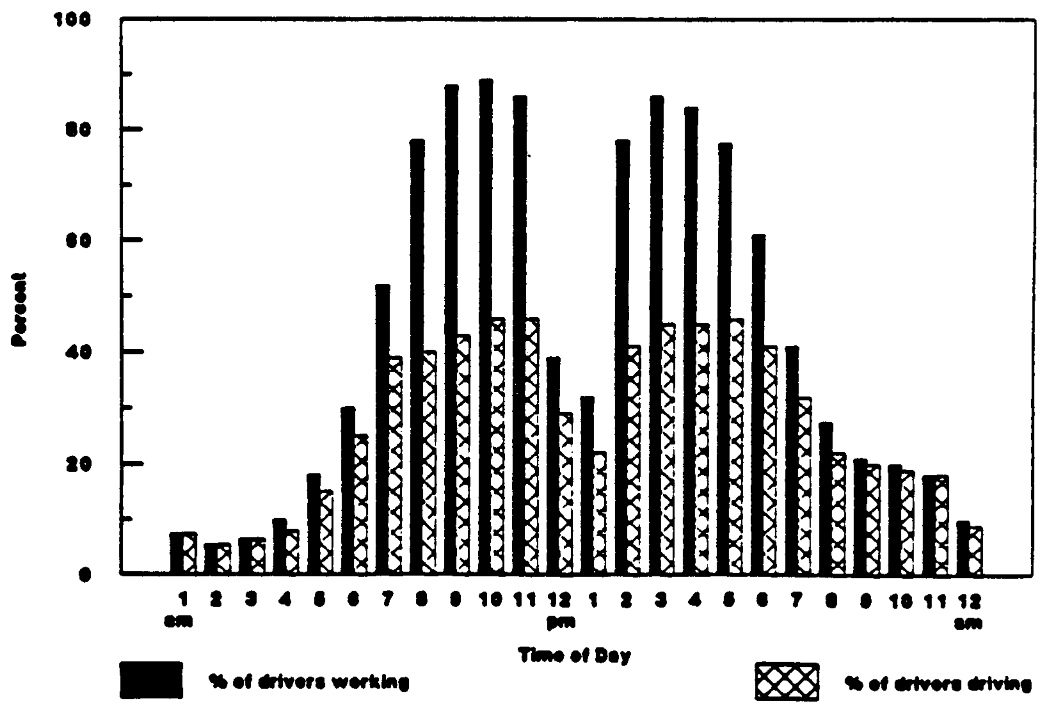
Figure 20

Truck Driver Activity Levels by Time of Day

Drivers Coming Back Home Every Day

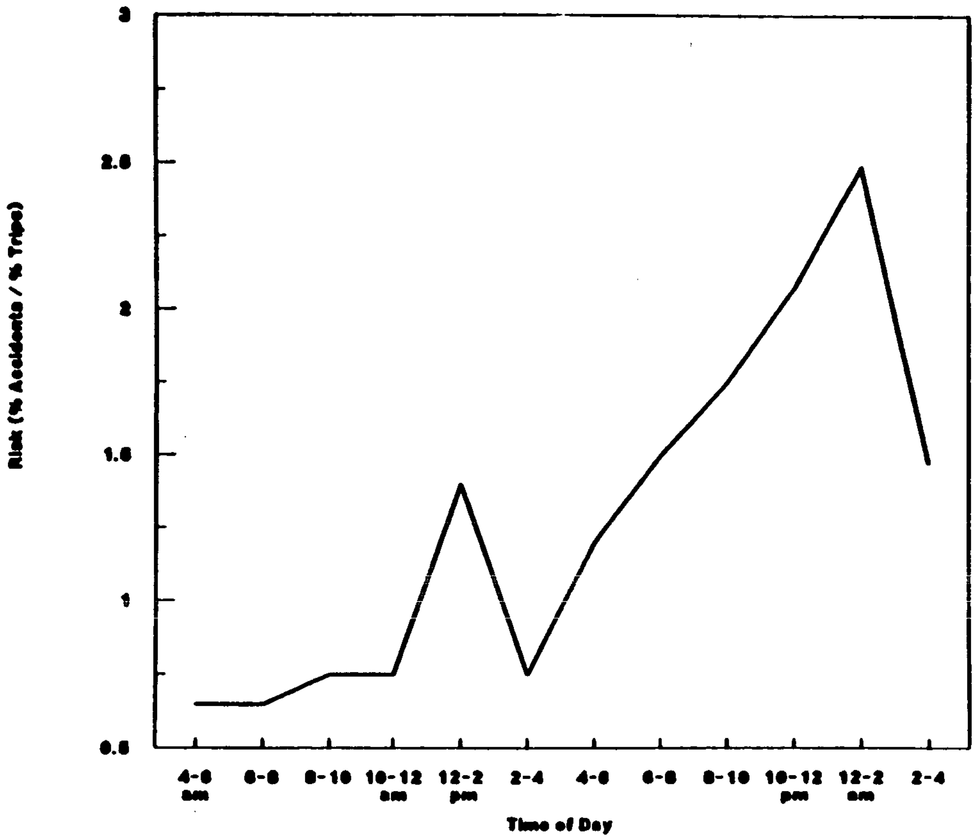


Drivers Away From Home - 2 Days or More



Source: Hamelin, 1987

Figure 21
Truck Driver Risk by Time of Day



Source: Hamelin, 1987

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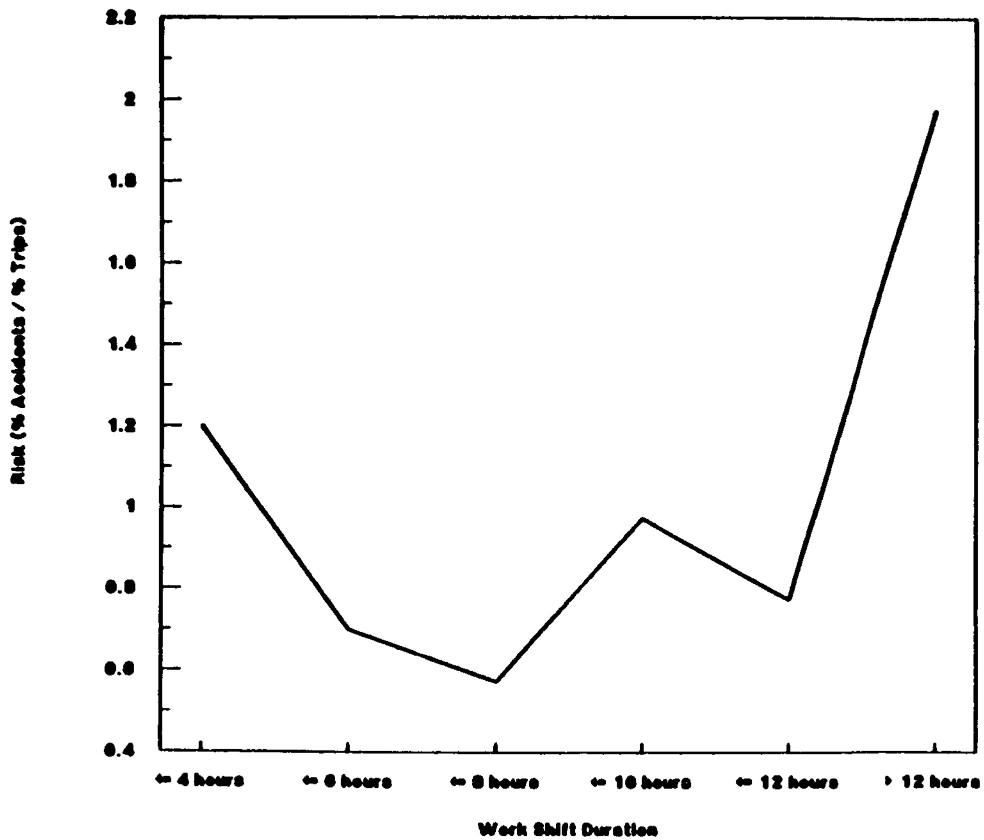
Figure 22
Truck Driver Risk and Duration of Activities



Source: Hamelin, 1987

Significant increases in driver errors and decreases in alertness have been noted as early as the fourth hour of driving time in a shift, and generally increase throughout the trip, except for a slight recovery near the end of the trip (Harris and Mackie, 1972). The lowest levels of alertness occur for most drivers between 2:00 a.m. and 7:00 a.m. Moreover, the adverse effects of prolonged driving are probably more pronounced for drivers aged 45 or older than for younger drivers. Thus, the greater experience of older drivers, a safety enhancement during the early hours of a shift, is offset somewhat by physical limitations of older drivers, if the shift duration exceeds a threshold. Finally, drivers on irregular schedules experienced more fatigue than drivers on regular schedules, and the effects tended to occur earlier (Mackie and Miller, 1978). Drivers using a sleeper cab for rest periods experienced greater fatigue than did relay drivers, although drivers who "rest" in the seat of their cabs were more prone to dozing on the road than those using the cab sleeper (Wyckoff, 1979).

As noted in Figure 23, accident data involving interstate commercial motor vehicle drivers show fatigue-classified accidents as proportionally higher during the hours between 11:00 p.m. and 8:00 a.m., emphasizing the importance of circadian rhythm (Hackman et al., 1978). The NTSB, too, notes fatigue (or hours of service) as a factor in over 30 percent of its accident investigations (NTSB, 1987). Instances of 26-31 consecutive hours of driver duty time prior to the accident were documented, some as a direct result of carrier dispatch, delivery, or other requirements.

A relationship between heavy-truck accident severity and accident occurrence by time of day is also apparent. Figure 24 shows that a disproportionately larger number of fatal accidents occur between midnight and 6:00 a.m. Although fatigue may be a contributing factor, this may also be due to problems associated with dark conditions. However, a higher accident severity associated with accidents attributed to dozing was also reported by Wyckoff (1979).

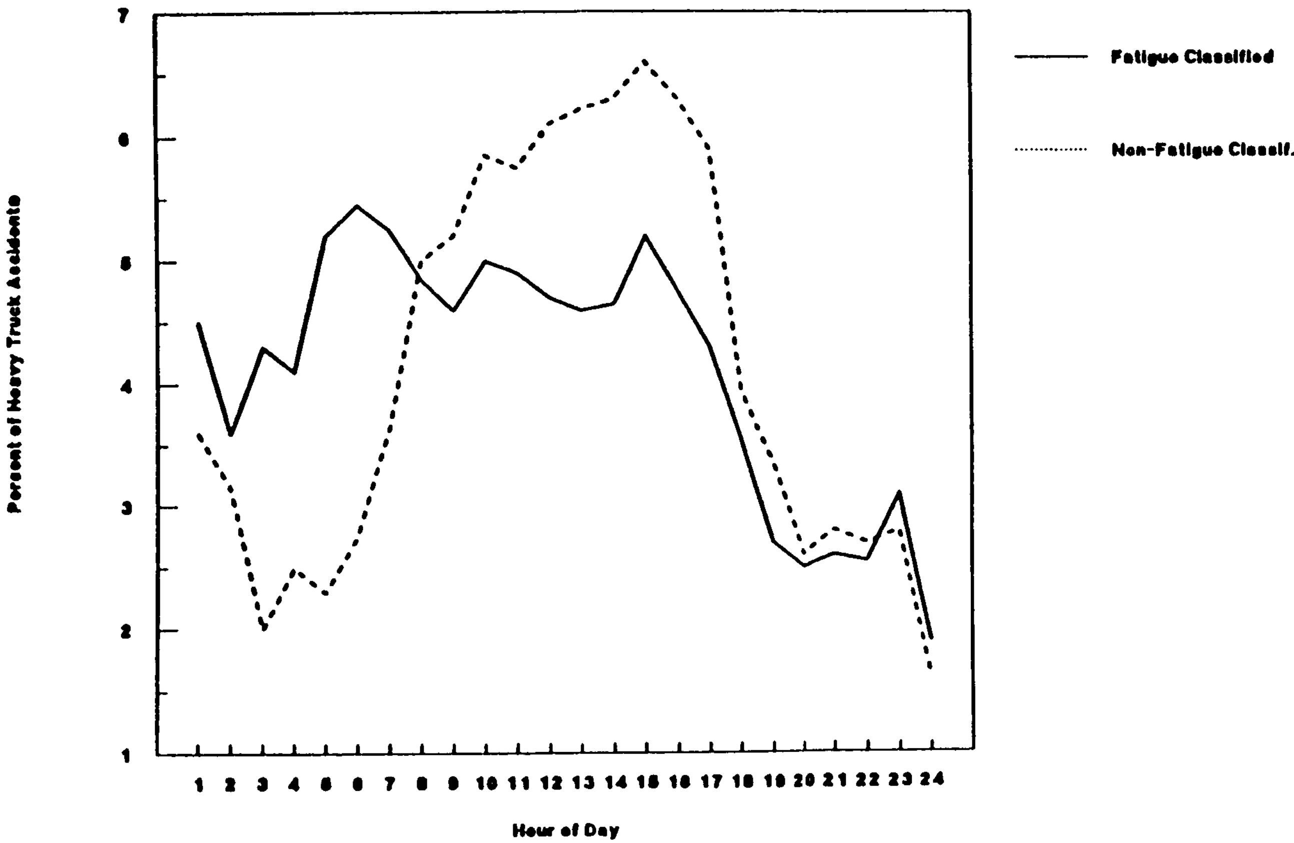
4.2.2 Vehicle Factors

Vehicle design and performance affect truck safety, as do maintenance and operating practices. Design and performance issues involve brake system capabilities, handling and stability, vehicle crashworthiness, and truck occupant protection. Maintenance practices include preventive maintenance as well as replacement of inoperable or worn parts. Vehicle operating practices include cargo loading, both in terms of tiedown, overall weight, and weight distribution.

The impact of vehicle factors in an accident may be more subtle than driver factors. Vehicle factors may not precipitate a crash but can reduce the vehicle's performance capabilities below the threshold where safety can be maintained when an unusual driver action is taken. These factors are also more likely to have a significant role in highway operating environments, such as heavy traffic, curves, or narrow roadways, where peak vehicle performance may be needed.

The subtleties of the role of the vehicle in accidents are emphasized in an examination of Oregon accident records for heavy trucks. Vehicle defects were not typically the designated cause of an accident (Oregon Public Utility

Figure 23
Fatigue and Non-Fatigue Classified Truck Accidents by Hour of Day



Source: Hackman, et al., 1978

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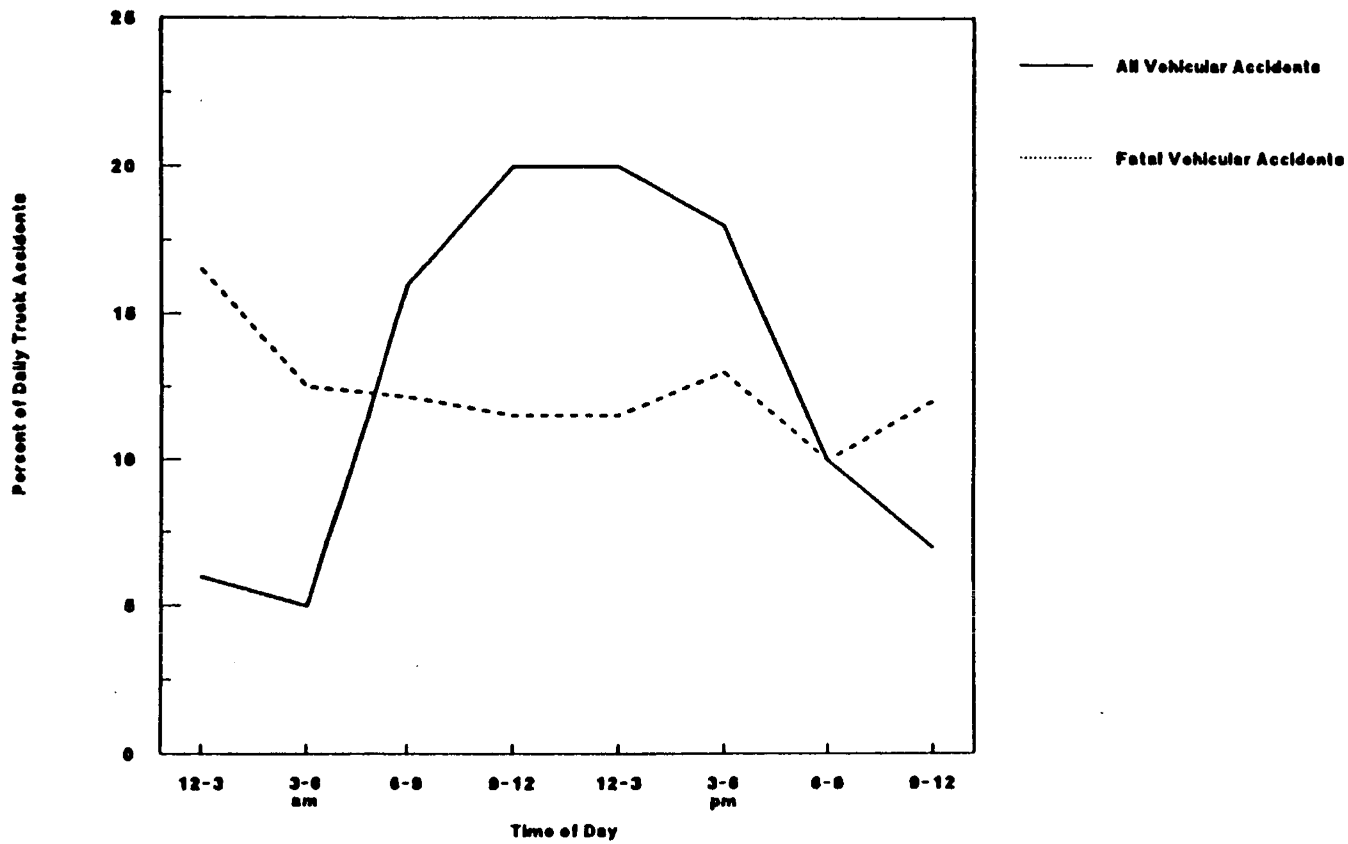
Figure 24
All Accident and Fatal Accident Involvements by Time of Day for Combination Trucks



Source: NHTSA, 1987

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Commissioner, 1985). However, when truck-at-fault accidents were disaggregated, over 20 percent of the accidents were linked to mechanical defects. Given the known biases toward driver error as the reported cause of an accident, this analysis identifies vehicle factors as important for accident prevention as well as for mitigating accident severity.

4.2.2.1 Braking System

Problems associated with vehicle maintenance are evident in the results of State-conducted vehicle inspections as part of the Federal Motor Carrier Safety Assistance Program (MCSAP). Although the results vary among States for reasons which may be related to the process of selecting vehicles for inspection, the condition of much existing equipment is so deficient that a significant number of trucks are placed out of service immediately. Based on all cited equipment violations, brakes are listed as the most common problem, followed by poor lighting and tire condition. Accident causation studies also corroborate this relationship. Of all heavy-truck accidents associated with mechanical defects, brake system failures were the single largest group cited, constituting 31 percent of the total (BMCS, 1979).

The nature of brake problems has been documented in greater detail by the Oregon Public Utility Commission, which found that over 60 percent of brake violations related to brakes being out-of-adjustment; another 14 percent related to problems with the brake lining. Therefore, roughly three of every four brake-related citations identified problems that normal brake maintenance could easily detect and correct. NTSB's investigations revealed that in many cases the truck driver had responsibility for proper brake adjustment, but the carrier had not required or furnished appropriate training (NTSB, 1987).

Existing truck braking systems must be kept adjusted and well maintained to accommodate sudden braking or other avoidance maneuvers without causing the truck to jackknife, which is considered a significant problem today. Jackknifing potential is exacerbated by wet road conditions, and is especially prevalent among lightly loaded or empty vehicles (Jones and Stein, 1988; Winkler, et al., 1983).

4.2.2.2 Vehicle Handling and Stability

Handling and stability problems often lead to vehicle rollovers, which, in turn, are strongly correlated with accident severity. Rollovers are more likely to be associated with accidents involving a fatality relative to all heavy-truck accidents (NHTSA, 1987). Other studies show that the risk of injury is higher in rollover accidents involving a single vehicle relative to multiple-vehicle accidents (Jones and Stein, 1988).

Rollovers are more likely to occur on curved roads, where vehicle contributory factors include load shifting, deficient brakes, and deficient tires (NHTSA, 1987). Driver-related factors include inattention, falling asleep, loss-of-control/skidding, speeding, and avoidance maneuvers. Operational factors, such as unbalanced cargo loads and trailers with higher centers of gravity, are also more likely to be found in rollover accidents.

4.2.2.3 Tires

Tire failure is the second leading cause of crashes having mechanical defects as primary contributing factors (IIHS, 1985), and is thought by heavy-truck drivers to be the most failure-prone part of the truck that affects safety (Regular Common Carrier Conference, 1987). Trucks carrying heavy loads may have underinflated or overheated tires, conditions likely to lead to blowout or fire, and often, loss of control.

4.2.2.4 Override/Underride

When accidents occur between large trucks and cars, the mismatch between truck and car bumper heights leads to override and underride consequences. Override/underride accidents are more prevalent at night, when darkness reduces visibility for all drivers. This problem is more evident for certain trailer configurations, particularly platform trailers (MVMA, 1985).

A comparison between fatal and nonfatal car-into-truck accidents shows that fatalities occur more frequently in underride accidents, including many from contact with the side of the truck. Trucks and trailers with devices to prevent underride were more likely to be involved in nonfatal accidents, showing the value of such protection (MVMA, 1985).

4.2.2.5 Truck Occupant Protection

Fewer than 1 percent of all medium- and heavy-truck occupants involved in accidents are killed, and only 10 percent are injured. Nevertheless, truck driving is considered a relatively dangerous occupation when compared to other occupational fatality rates (NHTSA, 1987).

It is interesting to note that the majority of truck drivers (76 percent) involved in accidents were not wearing seat belts at the time, based on analysis of NASS data. A truck driver wearing a seat belt is much less likely to be injured or will suffer a less severe injury in an accident, primarily because he is less likely to be thrown out of the cab by the impact. FARS (1984) data indicate that total or partial ejection was involved in 38 percent of combination-unit (tractor-trailer) truck occupant fatalities. Ejection after an accident also occurred more frequently among truck occupants than it did among passenger car occupants (NHTSA, 1987).

For those truck-occupant accident victims who remain in the cab, entrapment, cab crush, and contact with interior surfaces pose serious consequences. A study of truck occupants in rural accidents identified ejection and steering-assembly contact as the leading sources of truck occupant injury, followed by contact with the windshield and the door area (Robinson, 1969). A study of injury patterns of fatally injured truck drivers concluded that severe abdominal injuries in combination with head and/or chest injuries were more likely among combination-unit truck drivers than among drivers of other truck types (Karlson, et al., 1977). The nature of these injuries suggests the steering wheel as particularly dangerous. The steering wheel was also identified as the most prominent source of injury in an analysis of 124 accidents involving Volvo trucks in Sweden (Anderson, et al., 1980).

Limited information is available on the relative safety of cab-over-engines (COE) and conventional cabs. There is some indication that the risk of injury to a COE driver is slightly (15 percent) higher, and the risk of injury to the nontruck driver slightly lower, when a COE is involved (MVMA, 1985). FARS data show that COEs have a greater involvement in accidents in which a fatality occurs as well as in accidents involving a truck-driver fatality. These findings are worthy of note since the advent of the COE design was motivated by Federal restrictions on overall length, which are no longer operative.

There have also been findings reported on the discomforts of prolonged exposure to driving and the potential for decreased driver performance and permanent harm to the body. The greatest concern among heavy-truck drivers is seat comfort, vibration, temperature, noise and fumes (Wyckoff, 1979). Drivers report a higher frequency of hernia, back, kidney and nervous problems when compared to the public. There is further evidence that those who spend more than half of their working lives driving are three times more likely to suffer back trouble than the rest of the population (Troup, 1978). The drivers surveyed for one study attributed 14 percent of their previous accidents to poor ride quality, and noted that vibration was more of a problem when vehicles were empty (Wilson and Horner, 1979). A Swedish research study also reports professional driver complaints about noise, exhaust, climate, uncomfortable seats and heavy lifting, leading to back and stomach trouble as well as heart and circulatory problems (Lipping, 1980).

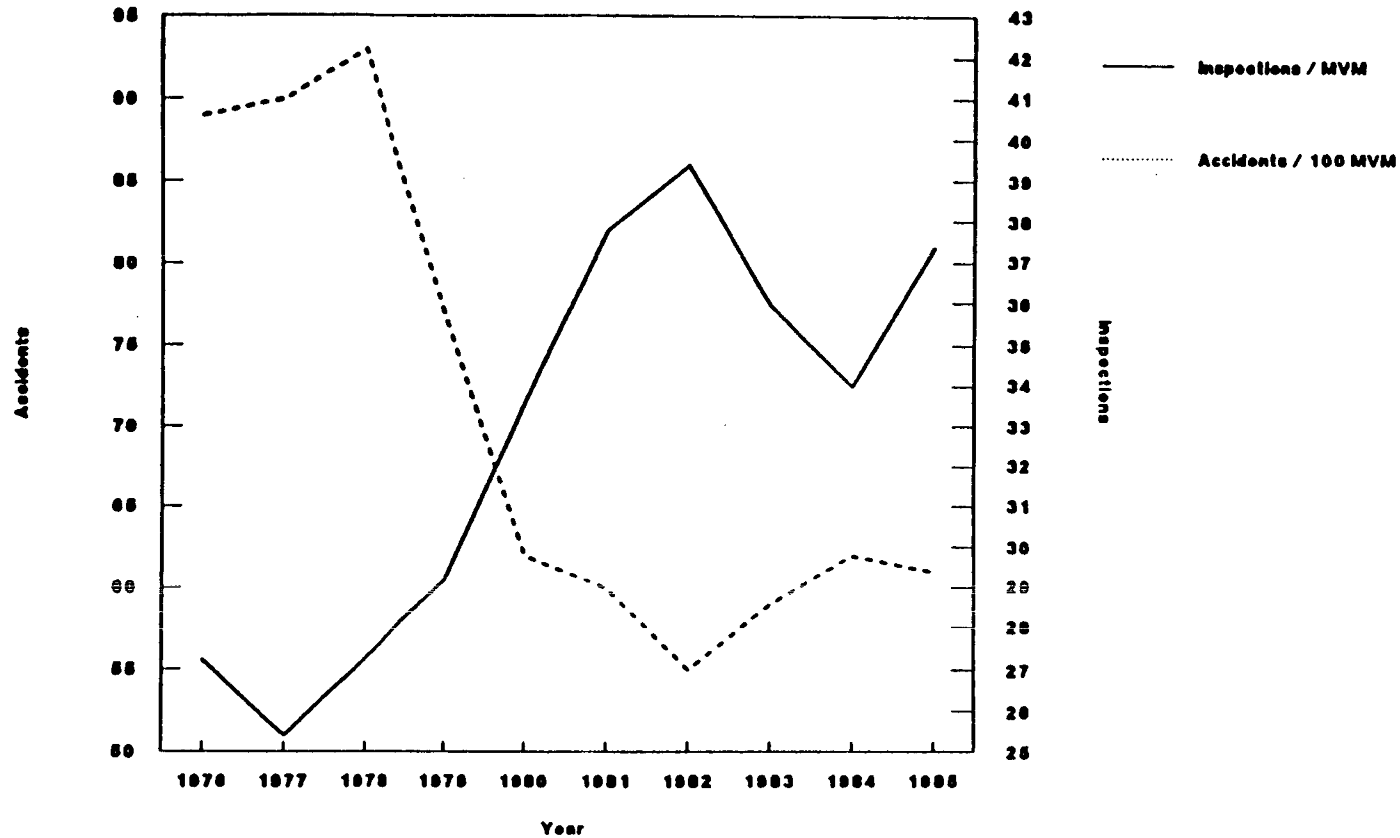
The Society of Automotive Engineers reports that truck driver exposure to noise is greatest during freeway hauls and that permanent hearing loss hazard may exist. They found that frequent use of radio or CB radio can significantly increase this hazard (Reif, et al., 1980), although the use of a CB radio has also been credited with increased driver alertness (Wyckoff, 1979).

Toxic gases in heavy diesel truck cabs have also been found to exceed thresholds for significant occupational exposure concentration in many vehicles. Cab floor openings have been identified as a principal pathway for engine compartment gas transmission into the cab (Ziskind, et al., 1977).

4.2.3 Safety Oversight

Roadside inspections can serve as effective accident prevention measures. As shown in Figure 25, a State of California study found a clear inverse relationship between the number of roadside inspections and the number of truck at-fault accidents (California Highway Patrol, 1986). Although other factors undoubtedly influenced operations over this 10-year study period, the apparent correlation between increased enforcement and upgraded on-the-road safety is hard to ignore.

Figure 25
California Truck Inspection and Truck Accident Rate for California State Highways (1976-1985)



Source: California Highway Patrol, 1986

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State terminal audits conducted as part of the MCSAP program also raise important carrier management safety issues. In Arizona, for instance, the three most common carrier violations are (1) failure to maintain driver qualification files, (2) hours-of-service violations, and (3) failure to maintain inspection, repair, and maintenance records. Officials familiar with Oregon's audit results concluded that carriers do not comply with the requirements because they typically do not either know or understand the regulations as applied to their operations. Moreover, even when the regulations are understood, the cost of noncompliance is so low that is it not an effective deterrent. These findings point to the need for a better education and enforcement program.

In Michigan, a direct link has been established between driver qualifications, hours of service, and vehicle operations and commercial vehicle accidents. Making compliance with driver qualification procedures a direct responsibility of carriers has proven to be beneficial to accident prevention.

4.2.4 Economic Factors

The U.S. trucking industry represents a diverse mix of carriers, drivers, and truck owners operating with a broad range of safety practices and levels of management control. Some limited evidence links the amount of motor carrier investment in safety-related activities to the firm's overall financial condition. One study of for-hire, general freight carriers found that the average carrier that eventually goes bankrupt spends less on safety and maintenance, has older equipment, and depends more on owner-operators (Chow, 1987). However, the basis for this finding was not a comparison of accident rates to carrier profitability, but rather a comparison of expenditures that infer safety performance to a weighted combination of financial ratios. Moreover, studies of this kind are hampered by scarcity of industry financial data maintained by the Interstate Commerce Commission (ICC), particularly for new entrants. Furthermore, ICC is eliminating requirements for detailed financial reports from those carriers who must still submit records.

The question of whether the preponderance of driver speeding is related to the method of compensation extended to drivers has been examined in one study. Drivers paid by the job have an economic incentive to speed, to produce more revenue-generating trips within a given time period. Based on analysis of NASS data, although speeding is prevalent across all segments of the carrier industry, speed is more frequently abused by ICC-exempt and for-hire carriers. Leased drivers had the highest incidence of previous speeding violations, as well as previous license suspensions and revocations. Leased drivers and drivers operating for ICC-exempt carriers were disproportionately involved in drunk driving accidents. The validity of these figures, however, is difficult to establish because the NASS data does not have well-defined driver or carrier classification categories. Furthermore, it is difficult to delineate the class of driver on a specific trip, as the same driver could be leased or not leased in many different driver classifications and may drive during the year in many different types of operation.

4.2.5 Roadway Environment Considerations

Like several of the vehicle-related issues, roadway environment factors are often listed incidentally on many accident reports. Typically, these factors make it easier for an accident to occur or create conditions that are unforgiving of mishaps or errors. Examples include road design/geometry, weather, lighting conditions, traffic conflict opportunity, and operating speeds.

4.2.5.1 Road Type

The functional class of the roadway has a profound impact on heavy-truck involvement rates for both fatal and non-fatal accidents (see Table 5). A similar relationship between rural/urban and interstate/other roadway fatality rates apppears in a corroborating study, although the magnitudes differ somewhat (Carsten, 1987).

Figure 26 depicts frequencies of heavy-truck accidents and fatal heavy-truck accidents by road classification. Of particular significance is the proportion of heavy-truck, fatal accidents (relative to all heavy-truck accidents) that occur on U.S. and State highways.

Some characteristics of these roads create the potential for severe accidents. For instance, the presence or absence of median control has a profound influence on accident severity. Fatalities are far more likely in accidents occurring on roads that are not physically divided and provide greater opportunity for head-on collisions. Furthermore, roads with higher posted speed limits are more likely to be the site of fatal truck accidents.

4.2.5.2 Lighting Conditions

The impact of lighting conditions on heavy-truck accident rates is not entirely known. Several studies find that the risk to truck safety is 1.5-2.0 times greater at night than in the daytime (MVMA, 1985). Other studies report a higher truck accident rate in darkness during the summer but a comparable accident rate for daylight and darkness during the winter season*, or find no

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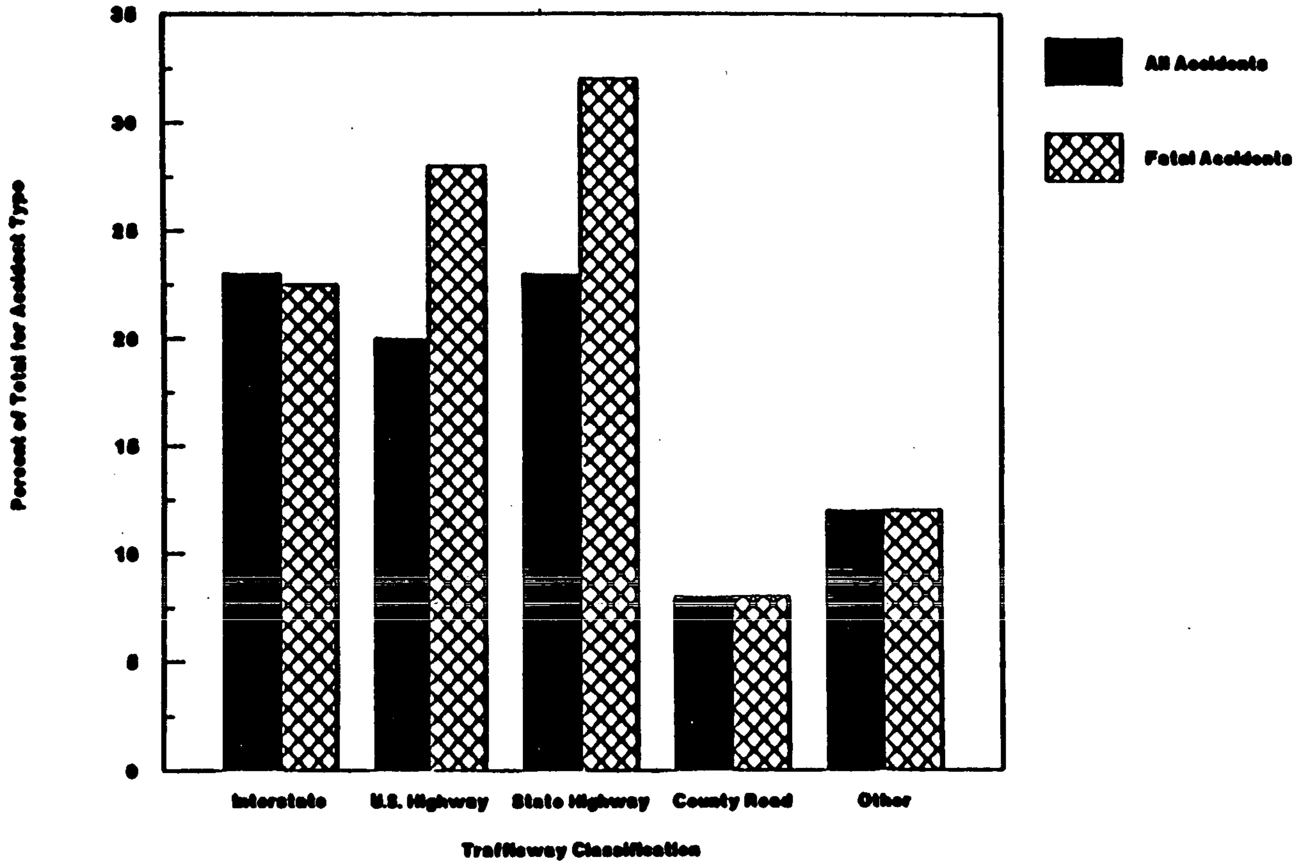
*A higher accident rate in darkness during the summer may be due to the fact that darkness is more concentrated in the late-night/early-morning hours (when fatigue would be more apparent) in comparison to winter lighting conditions.

Table 5. Single Trailer Vehicular Accident Involvement Rates by Highway Functional Class

Functional Class	Involvement Rate (per 100 million vehicle-miles)	
	Fatal	Non-Fatal Injury
Rural interstate	1.87	25.53
Rural-other principal artery	3.80	31.43
Rural minor arterial	6.49	41.65
Rural major collector	13.67	50.12
Urban interstate	2.23	52.73
Urban-other principal artery	9.52	103.41
Urban local	27.79	55.59

Source: Federal Highway Administration, 1987.

Figure 26
Truck Accidents by Trafficway



Source: NASS, 1981-86; FARS, 1983

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significant impact of lighting conditions (Strandberg, 1987). However, an apparent correlation exists between lighting conditions and accident severity. Based on NASS and FARS analyses, 40 percent of fatal accidents involving heavy trucks occur at night, in contrast to 24 percent of all heavy-truck accidents.

4.2.5.3 Sharing the Road

Annual studies of heavy-truck accidents carried out by the California Highway Patrol place trucks at fault 43-53 percent of the time over the past 10 years (NHTSA, 1987). A European study reports that in accidents involving a heavy-truck and another vehicle, the driver of the other vehicle involved was mainly responsible 44 percent of the time (Theis, 1987). An American Automobile Association-sponsored study of multiple vehicle accidents involving heavy trucks in Michigan notes that the non-truck driver was considered at fault in 69 percent of fatal accidents and 49 percent of accidents requiring hospitalization. These results suggest that, in addition to developing policies directed at reducing aggressive and irresponsible behavior of truck drivers, emphasis must also be placed on improving public awareness of truck operations and safety requirements.

4.2.6 Human Factors Policy Considerations for Improving Truck Safety

A review of the previous discussion suggests several policy considerations related to the effects of human factors on the safety of nuclear waste transport by truck. It is apparent that the driver is most frequently the key factor in determining whether or not a vehicular accident occurs under difficult driving conditions. A large number of heavy-truck drivers involved in accidents have poor driving records, including speeding offenses and other unsafe maneuvers that are major causes of accidents. Moreover, the correlation between drivers under the influence of alcohol with increased accident likelihood and severity is a major safety concern. Accident studies and surveys indicate that a major portion of the heavy-truck driver population has not received any driver training prior to going on the road. Young, inexperienced drivers are particularly susceptible to accident risk.

Fatigue can play a major role in accidents, particularly for young drivers during early shift hours and older drivers after extended shift length. Drivers of large trucks have shown significant increases in driving errors and decreases in driver alertness due to fatigue well within the current hours-of-service limit. Greater understanding of the circadian rhythm (time-of-day) impact on fatigue also suggests that current hours-of-service regulations and management assignment practices need additional examination.

Vehicle design and operating characteristics have a significant impact on safety. Brake systems are most in need of attention, with brake maintenance a principal concern. The prevention of jackknifing also deserves special attention. Handling and stability problems increase the likelihood of rollover. Tire condition and performance are also key factors in safely handling a big rig. Occurrences of override/underride, particularly at night, are common, suggesting that trailer design and visibility are issues that warrant close attention. Truck occupants typically do not protect themselves by wearing seat belts. As a result, ejection and contact with the cab interior often occur, leading to a higher likelihood of a serious injury or a fatality. Furthermore, truck operators are subjected to noise, vibration and other effects of prolonged truck driving which may lead to performance degradation and health impairment.

The roadway environment is recognized as a vital part of the safety equation. U.S. and State highways are disproportionately involved in fatal heavy-truck accidents, where the absence of sturdy median barriers has a profound impact on safety. The need for cars and trucks to share the roads safely deserves attention. The driving public must be made more fully aware of human factors in transportation and the potentially life-threatening consequences of a multiple-vehicle crash involving a heavy-truck. Further, in light of higher posted speed limits and increased speed variation on roads, and the overinvolvement of speed in fatal accidents, DOE may wish to restrict truck speeds on certain roads.

Drivers who frequently or sometimes carry hazardous cargo reportedly drive at slightly lower average cruising speeds and have better records with regard to moving violations and abusing the 10-hour driving limit (Wyckoff, 1979). These drivers tend to be slightly older and are less likely to drive while intoxicated.

On the other hand, drivers involved in the transport of hazardous cargo perceive they are less alert than other drivers. They also report higher incidences of ulcers, nervousness and headaches. Furthermore, even though they reportedly drive fewer hours, these drivers have more complaints about long driving hours and a heightened concern over the safety of equipment they are using, particularly trailers (Wyckoff, 1979). Many of these symptoms may be due to the increased stress associated with handling dangerous goods.

In the discussion to follow, additional background is provided in areas where truck transport policy development may be contemplated.

4.2.6.1 Driver Licensing

Recent Federal legislation has been directed at commercial vehicle operator licensing through passage of the 1986 Motor Carrier Safety Act. The Commercial Driver's License Program is currently under development with five key dates established as milestones for the implementation process. Effective July 1, 1987, it became illegal for a commercial motor carrier driver to have more than one driver's license. On July 15, 1988, standards for testing drivers and issuing licenses were distributed, including a provision requiring drivers intending to transport hazardous materials to pass specialized tests. By January, 1989, a nationwide information clearinghouse for exchanging license and violation information must be operable. After April 1, 1992, it will be illegal for a person to operate a commercial vehicle without passing the required written and driving tests. Finally, on September 30, 1993, States must adopt and administer programs to enforce testing and licensing standards, accept the qualifications and penalties, or risk losing Federal highway funds.

Concerned safety officials both in industry and government hope that this legislation provides for a program that can identify unqualified and irresponsible drivers and remove them from the road. As noted by the schedule, however, the means to do so will be phased in gradually over several years and will delay any immediate impact. Also, adequate monitoring of compliance and enforcement by the Federal Government will be required to make the legislation effective.

In implementing this program, concern has also been expressed over closing loopholes which presently allow commercial vehicle drivers considerable latitude in maintaining eligibility. For example, under present Federal regulations, a commercial vehicle driver may be disqualified only if his/her State license has been suspended or revoked, or if one of four types of traffic violations has been committed. Furthermore, a driver who commits a specified disqualifying offense while driving a non-commercial vehicle or while driving a commercial vehicle off-duty, is not subject to disqualification. In addition, drivers who are not regularly employed by a motor carrier and who drive commercial vehicles on an occasional basis are exempt from several Federal qualification standards (NTSB, 1986).

4.2.6.2 Driver Selection

The task of driving a truck is considerably more demanding than operating a passenger car. Commercial vehicle driving requires more attention and demands greater skills, both in normal driving situations and in responding to potential hazards (TRB, 1987). Large trucks are much less maneuverable than automobiles, and require greater distances for passing, stopping, turning and accelerating. As a result, a heavy-truck driver must possess the abilities to consistently anticipate potential traffic conflicts and, when confronted with it, be able to take an effective evasive action. The identification of qualified drivers places considerable responsibility on the part of carrier management to make appropriate hiring decisions.

According to Federal regulation, motor carriers must require all driver applicants to complete a written application and within 30 days after hiring a driver, to inquire with State licensing authorities and previous employers about the new employee's record during the preceding 3 years (NTSB, 1986). Although the written application content requirements are rather explicit, little guidance has been given concerning inquiries other than the requirement to maintain a record of the investigations.

An additional Federal requirement is imposed on motor carriers to administer road tests to new drivers, for determining their fitness to handle the equipment to which they will be assigned. The test must be given in the type of vehicle the new driver will be operating, and must cover several aspects of truck operation. The regulations do not specify the qualification of the examiner or method of evaluation, and provide more latitude to owner-operators in that the road test must be given by a person (other than himself) who is supposedly competent to evaluate the driver's skills. Furthermore, exemptions may be granted to drivers who hold certain licenses or have passed the required road test administered by another company in the preceding three years.

Finally, the Federal regulations include a written "examination" requirement for all new drivers. This test consists of 66 questions, which are printed, along with the answers, in the Federal regulations. While taking the test, the driver may refer to the answer list. Furthermore, even if the driver scores poorly on the test, these results may not affect his or her qualifications, and employment may not be denied on the basis of a low score. Owner-operators do not have to take the knowledge examination required of other drivers.

Aside from the obvious problems associated with the written examination requirements, in practice the regulations are often ignored or interpreted with considerable latitude. Although the Commercial Driver's License Program is likely to address some of the expressed concerns with driver qualifications, it will not be a direct substitute for a motor carrier's determination of whether a driver is sufficiently skilled to handle the exacting requirements of the type of work in which he/she will be engaged.

For this reason, many carriers concerned with safe highway operations follow a careful driver hiring process that often involves referral, interviews, background checks on employment and driving records, and pre-employment physicals. Such care reflects a corporate management philosophy that not everyone is capable of operating a heavy rig. One company has adopted the use of psychological testing to assist in determining the applicants who have the coordination, physical capability and mental attitude to handle a tractor-trailer combination (OTA, 1988). It has found a very strong correlation between these evaluative procedures and driver performance after hiring. This carrier's commitment to a sophisticated driver selection process contrasts with findings from a study of carriers in the Pacific Northwest which showed that 35% of firms performed unsatisfactorily in qualifying their drivers.

While attempts to develop more stringent screening procedures is encouraging, economic pressure on the industry is working to hamper this progress. The Department of Labor reports that the truck driving work force is expected to increase 17% by 1995, placing truck driving among the 37 fastest growing occupations, out of 500 studied (NTSB, 1986).

At the same time, industry analysts forecast that finding qualified truck drivers will become more difficult over the next decade, with a 30% reduction in the driver pool expected by 1992. This reduction will be due to retirements, drug screening, tighter Federal driver requirements and licensing standards, a shrinking national labor force, and the perception that truck driving is a high-stress job requiring excessive time away from home (Winsor, 1987).

Thus, although the importance of the driver selection process in screening out unqualified drivers in advance is well recognized by many carriers, unless the entire industry uses uniformly stringent driver selection practices, problem drivers will continue to enter the work force in great numbers. They will merely be reshuffled to less safety-conscious firms within the industry, creating a large group of high-risk motor carriers.

4.2.6.3 Alcohol and Drug Use Among Prospective and Current Drivers

Currently, the Federal Motor Carrier Safety Regulations prohibit possession or use of an intoxicating beverage or drug while on duty, and from consuming or being under the influence of an intoxicating beverage within four hours before going on duty. Furthermore, a person is not qualified to drive if he/she has a current clinical diagnosis of alcoholism or drug dependency.

These rules were promulgated based on the knowledge that driving while intoxicated or under the influence of drugs is directly associated with a degradation in driving performance. While the human response to the ingestion of drugs and alcohol varies depending on characteristics of the individual and environment (Drew, et al., 1959), it has been demonstrated that, for the majority of subjects, human performance decreases at BAC (blood-alcohol concentration) levels of 0.05 percent or below*. Epidemiological studies also indicate that the risk of being involved, as well as at-fault, in a motor vehicle accident begin increasing at low BAC levels (TRB, 1987). This is in contrast to a legal standard for intoxification in highway driving which is currently set at 0.10 BAC in most States.

The basis for much of the previously cited research findings has been automobile, rather than heavy-truck, driving performance. The transferability of these findings to heavy-truck drivers, who operate a different vehicle and who drive as a profession, warrants some consideration. Previous studies suggest that although more skilled persons are better able to compensate for the effects of alcohol than individuals who are less skilled, even skilled drivers show a decreased ability to handle divided-action tasks at low BAC levels. Unfortunately, divided-action tasks are much more prevalent in a potential accident situation. Furthermore, as noted previously, many heavy-truck drivers have not received prior training and have had such little on-the-road experience, that they should not be considered skilled drivers as it relates to this discussion.

Recognizing the dangers of drug and alcohol use in the driver work force, many carriers have started to require pre-employment drug and alcohol testing. When one company started a drug-alcohol testing program two years ago, 15% of the applicants tested positive in the first year; a year later, only 8% of applicants tested positive (OTA, 1988). This company had sent a signal to prospective drivers that they need not apply if they have a drug or alcohol problem; however, such individuals are not precluded from seeking employment as a driver for other carriers with less stringent screening policies. This concern is substantiated from the results of a carrier screening applicants in the Midwest, where it was reported that 47% of the applicants had positive drug screens (Landis, 1986).

The drug problem among employees may also be more entrenched than originally acknowledged. The safety director of a motor carrier, while making spot checks of his company's tractors, found evidence of marijuana use; a subsequent investigation led to the discharge of 50% of the drivers at the terminal involved. In another instance, a laboratory which performs drug screening for several major carriers found that even for repeat examinations, 13-18% of the tests were positive. In some cases, this occurred despite the fact that employees were given 30-60 days advance notice that the tests were to be conducted (OTA, 1988).

Establishing formal procedures for periodic drug and alcohol testing of employees has been the subject of much debate. Many motor carriers conduct testing on a calendar basis for all employees; others test a sample of employees. An agreement between carrier management and the International

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*The most widely used measure of blood-alcohol concentration is the grams of alcohol per milliliter of blood, and is expressed as "percent BAC" (TRB, 1987).

Brotherhood of Teamsters, reached in 1984, provides guidelines for periodic drug and alcohol testing. Members can be tested during their recurrent DOT physical examinations and when probable cause can be established from appearance, behavior, speech or breath odor of an employee (TRB, 1987). Although the Teamsters represent many drivers working for large trucking operations, the vast majority of drivers are not subject to this agreement. It has been estimated that carriers of sufficient size to mount their own alcohol and drug abuse programs are responsible for less than one-third of the heavy trucks using the highways. To the extent that independents contract with larger carriers, however, they fall under the company's policy.

In a survey of 1,762 truck drivers conducted recently in Florida, 33% of the drivers reported being previously tested for alcohol and 38% reported being previously tested for drugs by the company they were presently driving for or to which they were currently leased. Owner-operators reported the lowest frequency, 29% and 31% for company alcohol and drugs tests, respectively. Drivers working for for-hire carriers reported the largest percentage of prior testing. Over 25% of the drivers surveyed also reported having taken a lie detector test administered by the company they were driving for or to which they were leased. Of the drivers surveyed, 73% also stated they would approve mandatory random alcohol and drug testing by employers (Regular Common Carrier Conference, 1987).

Part of the concern over alcohol and drug testing is the reliability of the testing methods. Even the most accurate tests, which are also the most expensive ($30-$125), produce an error of 2-3 percent for non-drug users while passing up to 10 percent of drug users tested. Because of the likelihood of false readings, laboratory experts urge a follow-up test. However, many cost-conscious employers are not willing to invest these additional resources. Those more concerned about the individual share information with the applicant and are willing to re-evaluate the applicant if he or she wants to take a second test at personal expense.

One carrier has implemented a novel policy to resolve any differences in test results. If the first test is positive, the applicant is informed. If the applicant believes the test results are inaccurate, he pays for a confirmation test. Should the confirmation test be negative, the company reimburses the applicant and considers him for employment (Borzo, 1987).

Some carriers are also showing sensitivity to the counseling needs of drug and alcohol users. One carrier's employees are given a drug test as part of their annual physical examination. They are notified of their scheduled appointment 30 days in advance. If a driver notifies management prior to the physical that he has a drug or alcohol problem, the company assists the employee in obtaining treatment. The firm believes if an employee is able to admit to a problem, it has a responsibility to help him out, and that the employee has valuable characteristics if he can come forward under such circumstances. There is also a provision in the Teamsters agreement which permits an employee found to be under the influence to take a leave of absence to undergo treatment (OTA, 1988).

More stringent methods for alcohol detection of truck drivers while on the road has also been discussed as a public enforcement measure. A recent study conducted by the Transportation Research Board concluded that the technical ability to detect and measure BAC levels of less than 0.05 is available with current screening and testing devices. However, the legal ability of public authorities to enforce a low BAC standard with breath-screening devices has not been adjudicated at a definitive level. Should the ability to do so survive legal scrutiny, cost-effective enforcement could be carried out by administering screening of drivers at truck weigh stations and as part of vehicle safety inspections, along with mandatory blood tests following injury-producing accidents. TRB estimates that vigorous enforcement of this kind would save between 80-140 lives annually at a minimum BAC level of 0.10, 110-190 lives at a 0.04 BAC threshold, and 130-250 lives by enforcing a limit of 0.00 BAC. The total public and private costs for enforcement at each level is estimated at $30 million, $40 million and $50 million, respectively (TRB, 1987).

DOT has recently proposed to disqualify both interstate and intrastate truck drivers found to have an alcohol concentration above 0.04. First time violators would be subject to a one-year disqualification, while a second violation would result in a lifetime disqualification.

4.2.6.4 Management Approach

Driver attitude is thought by many to be a major factor influencing truck safety. A company's management can influence the employee work environment regarding safety. It is expected that if a carrier promotes safety in all of its activities and rewards safe practices, this will have an effect on a driver's perception of safety as a major job responsibility and his self-image as a professional, accountable for the safe operation of his vehicle.

One large motor carrier has determined that if the company's top management does not demonstrate a commitment to safety, then the organization will not be committed to safety either (OTA, 1988). This firm has adopted a formal corporate approach to safety. The focal points of its program include (1) driver selection, (2) driver training, (3) driver conditioning, and (4) managing the driver.

Communication is an important ingredient at another firm. For instance, rotational discussion groups are held between management and drivers to solicit organizational input. Not only does this show the driver that his opinion is valued by the organization, it also provides management with constructive feedback on operations. A third firm also has a considerable amount of communication with its personnel. The firm says that greater rapport between labor and management results in extensive agreement on where the organization is going and how it is going to get there. Many carriers have also structured various incentive programs to promote safety among their employees.

Should management practice a policy of creating an environment which does not compromise safety, this may entail balancing regulatory requirements and the quality of service offered to customers. The DOT hours-of-service rules combined with a movement in the economy towards just-in-time deliveries makes meeting these constraints a formidable challenge. One company is approaching this problem openly by informing customers that such trade-offs exist and that safety is a cost and concern relative to delivery timeliness. The American Trucking Associations (ATA) also advocate placing responsibility on shippers for demanding that truckers drive longer or faster than the law requires to deliver goods. Another expert assigns blame to brokers who often place constraints on both shippers and carriers for their own benefit (OTA, 1988).

What makes this problem so complex in today's trucking industry is the intense competition for freight. All carriers have on-going expenses and must have continuous revenues to meet them. Thus, the economic incentive for carriers to push drivers to the limit (and beyond) is quite strong as they attempt to attain a sufficient volume of business by employing all available truck capacity whenever necessary.

The management approach to safety also affects the relationship between a company dispatcher and driver. At one firm for instance, if a driver calls in to the dispatcher indicating that he is too tired to continue and that he needs to pull over, the dispatcher will not contest this request unless it becomes a chronic problem with the same individual. This is in contrast to other companies where the dispatcher will threaten to cite a driver for not meeting his assigned schedule (OTA, 1988).

Drivers complain that shippers and dispatchers often push hard for unrealistic delivery schedules that violate regulations. Currently, an oversupply of carriers exist, providing an environment in which shippers can shop around until they find a carrier willing to take a load on the shipper's terms. Under the circumstances, drivers feel it is unfair that they are held solely responsible for violations or accidents. The State of Rhode Island has acknowledged this inequity and is starting to spread the responsibility through the imposition of fines and citations upon motor carrier owners whenever their drivers are cited (OTA, 1988). At least one expert finds that drivers feel less pressured to take overloads in States where this change in policy has occurred.

4.2.6.5 Driver Training

Previous accident data analysis shows that truck drivers involved in accidents frequently lack formal training. This issue is recognized as requiring priority attention by the industry.

At present, there is no Federal requirement that drivers of heavy trucks receive any degree of formal training, nor is there a single State which imposes a training requirement for all drivers of heavy trucks (NTSB, 1986). Federal regulations establish qualifications on the basis of whether a person can safely operate the vehicle and secure the load being carried, which can be acquired through training or experience. Motor carriers do not impose training requirements, and often require applicants to have a minimum of two years of on-the-road experience irrespective of prior training. This poses difficulties for graduates of accredited training programs since the only way to meet this requirement is to drive for a firm not possessing such a requirement.

Formal truck driver education is available through proprietary truck driver training schools, non-profit public education institutions and in-house motor carrier training programs. The number of training programs are estimated at around 200, with fewer than 10 being in-house programs. Tuition ranges from $350-$5,000. There are also wide variations in course length, qualifications of the instructors, student/teacher ratio and, most importantly, time spent in and around the cab (NTSB, 1986).

Truck driver training schools may be subject to oversight from various licensing and accrediting bodies. Some States, such as Maryland, Pennsylvania and Indiana, require the licensing of driver training schools, although different agencies are assigned this oversight responsibility. Although these authorities often establish a minimum number of course hours, requirements concerning course content are usually not specified (NTSB, 1986). Some schools have been accredited by the National Association of Trade and Technical Schools (NATTS) or the National Home Study Council (NHSC). However, the vast majority of programs have not been accredited by either organization.

In an effort to establish a set of standards for truck driver training, in 1984 DOT issued proposed minimum standards for training tractor-trailer drivers. The standards call for a minimum 320-hour course, lasting eight weeks if taken on a full-time basis. Course content should include basic operation, safe operating practices, advanced operating practices, vehicle maintenance and non-vehicle activities. The standards also cover instructor qualifications, school facilities, graduation requirements and student placement. Although a truck driver training school can develop its own curriculum around these standards, in 1986 the Office of Motor Carriers published a ready-made curriculum, entitled Model Curriculum for Training Tractor-Trailer Drivers. Included in this document are instructions for the school administrator, instructor and student. Unfortunately, these standards cannot be used for evaluating existing schools until their validity has been tested with actual schools and students.

Concurrent with these developments, the trucking industry has been taking steps to promote effective training. The Trucking Industry Alliance was established in 1983 as an informal coalition of individuals and groups in trucking and related industries. The Alliance, in turn, established the Professional Truck Driver Institute of America (PTDIA). In an effort to define acceptable training standards, the PTDIA is in the process of certifying driver training programs. The PTDIA is funded entirely by voluntary industry contributions.

In instances where in-house training activities have been carried out, the results are encouraging. In 1980, a large, general commodities motor carrier implemented a training program whereby all new drivers are instructed in the safe handling of the vehicle and cargo. Since these training efforts were undertaken, the firm has reported a 13.5% decrease in line-haul accident frequency, despite a 36.8% increase in line-haul mileage. In another case, a trucking firm's commitment to training led to the provision of a curriculum, equipment, instructors and course evaluations as aids to outside training schools (OTA, 1988).

The insurance industry has also participated in the development of training programs to promote safe driving behavior. One insurance carrier has developed a five-day seminar, open to driver trainers, safety and maintenance supervisors, and management personnel of fleet policyholders. It includes both classroom and behind-the-wheel exposure. Of several fleets' safety records examined before and after receiving training, reductions in accident frequency and loss rate per vehicle were consistently reported.

Some discussion has also been raised concerning the development of a truck driver apprenticeship program. The reasoning behind this proposal is that qualified supervision can help ensure that a new driver develops safe driving habits. In the Netherlands, for example, new drivers undergo a two-year apprenticeship (NTSB, 1986).

There is no currently organized apprenticeship program for heavy-truck drivers in the United States, although the issue has been raised in the past. In 1971, DOT invited comment on proposed apprenticeship programs that would have enabled persons less than 21 years of age to operate commercial vehicles. This proposed rulemaking was subsequently closed without action.

Continuous training of current employees is also important not only to keep drivers up to date, but to identify bad habits which may have developed over time. For example, research in Europe has shown how little perception even experienced drivers have of their actual speed when they are in a monotonous or repetitive driving situation. Problems with speed perception can be particularly acute when a driver leaves the Interstate system and begins to operate on two-lane roads where speed limit, access, median control and signage are quite different.

Some carriers are also concerned about keeping drivers physically fit to handle the rigors of the job. One firm believes that physical conditioning, weight control and aerobic capacity are keys to reducing problems associated with fatigue and stress. Another is installing a conditioning program available nationwide for their line-haul drivers to encourage the right physical and mental condition to handle the unexpected events that daily confront their drivers.

4.2.6.6 Sharing the Road with the Driving Public

Many truckers rightly claim that most automobile drivers are not fully aware of the appropriate ways to share the roads with trucks. For instance, because of the increased stopping distances associated with truck braking, truck drivers in congested areas try to leave enough room between themselves and other vehicles to allow for a complete stop. However, automobile drivers often eliminate this space by cutting in front of trucks. Moreover, if the truck subsequently hits the rear of the car, the truck driver may be cited for the accident. Thus, while many unsafe truck drivers are undeniably operating on the nation's roads, there are also many poorly qualified car drivers sharing these highways.

An education program directed at the driving public could enhance awareness of safety issues related to sharing the road with trucks. States, such as Tennessee, are considering reorganizing their licensing programs to include material and questions on truck safety. They are also contemplating running a continuous showing of a tape on sharing the road with big trucks to people while waiting to obtain driver licenses.

Education programs to better inform small carriers about road safety have also been developed. Available through the National Safety Council and ATA, these materials describe how a carrier as small as a ten-person trucking company can implement a responsible safety program.

4.2.6.7 Hours of Service

The hours of service rules in effect today are essentially the same as those promulgated in 1937 and 1938 by the ICC*. The regulations prohibit carriers from requiring or permitting any driver to "drive" more than 10 hours, or to be "on duty" more than 15 hours in any (but not every) 24 consecutive hour period. Drivers are theoretically guaranteed 8 consecutive hours off-duty during that time period. In addition, drivers are prohibited from accumulating more than 60 on-duty hours in any week, or 70 on-duty hours in any period of eight consecutive days.

Extremely difficult to enforce, this rule is subject to problems ranging from blatant abuse to loose interpretations of "on duty" and "off duty." For example, tiring and strenuous activities, such as loading and unloading, done by the driver, are not considered "driving" time, although they clearly contribute to fatigue. Furthermore, eight hours of "off duty" time do not afford drivers adequate time to travel to and from their jobs, eat, bathe, and attend to life's other requirements, and to obtain eight hours of undisturbed sleep. Moreover, the 15 hour on-duty period can be interrupted during the course of a driver's overall tour for any number of hours if their employers "relieve" them of on-duty status for meals, rest breaks, or while their vehicles are being loaded and unloaded. Finally, the carrier-wide practice of requiring a driver to stand around a terminal in an "off-duty" status awaiting a work assignment contributes to fatigue prior to the tour of duty ever beginning.

First the ICC and subsequently DOT have openly acknowledged that the hours-of-service rules have been subjected to abusive practices. In 1972, the Bureau of Motor Carrier Safety (BMCS) in DOT initiated a comprehensive study of the relationship between dangerous levels of fatigue among truck drivers and the current hours-of-service regulations (Harris and Mackie, 1972). The report compiled and analyzed scientific and medical data reflecting driver performance and physiological responses collected during 195 truck and bus runs. A total of 1,550 hours of continuous data were obtained and analyzed on 62,000 miles of highway truck travel in all parts of the country, and in all weather and traffic conditions. The study concluded the following:

> The general findings of this study...indicate that driver performance deteriorates, driver alertness diminishes, rest breaks become less effective, and accident probability increases, all within the current 10-hour daily limitation on driving time. It (the regulation) is further at odds with a good deal of anecdotal evidence from the drivers to the effect that they do suffer from considerable fatigue but are unwilling to admit it because of the feared economic consequences. This situation is likely to remain as long as drivers are rewarded, as most are now, in direct proportion to the amount of time spent on the highway. In our opinion, this places economic reward in direct conflict with highway safety.

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* Trucking is not subject to the Fair Labor Standards Act. Carriers do not have to pay time-and-a-half for a greater than 40-hour work week. This creates an incentive for a carrier to hire the fewest drivers possible and to have them work the longest hours possible in order to maximize profit.

As a result of this study, BMCS admitted that the hours-of-service rules were unsatisfactory and in need of revision, but it did not take any formal regulatory action at that time. The just completed study had concentrated on scheduled relay operations of large common carriers whose drivers were able to plan their rest. BMCS acknowledged that further research was needed on non-regular route drivers who often could not predict when they would be assigned to driving tasks.

In 1978, BMCS issued the results of the second phase of their fatigue study. As expected, it was found that relay drivers operating on an irregular schedule suffered greater subjective fatigue, physiological stress, and performance degradation than drivers who work a similar number of hours on a regular schedule. It was also reported that fatigue effects are evident after about eight hours of relay truck driving when the schedule was regular and considerably earlier when the schedule was irregular. In addition, cargo loading was found to increase the severity of fatigue associated with irregular working schedules (Mackie and Miller, 1978). Finally, the reported findings were considered conservative since the drivers in the study were afforded the opportunity to obtain eight hours of sleep each night, clearly not always the case under conditions of uncertain and changing schedules.

In a separate, concurrent study of accident data, it was found that the number of driving hours alone was not related to frequency or severity of truck accidents. However, the combination of the driving and non-driving time may be related to driver fatigue and play a role in accident occurrence (Safety Management Institute, 1978).

Following the results of these studies, BMCS subsequently issued a Notice of Proposed Rulemaking (NPRM) and conducted public hearings in several cities around the country. By the end of 1978, BMCS had accumulated what it considered to be sufficient information to justify amending the hours-of-service regulations.

In 1981, however, the agency published a notice terminating the rulemaking action and closing the docket, citing the absence of a direct relationship between the hours of service rules and accidents. Also, in 1981, BMCS commissioned an economic study of the cost of modifying the hours of service rules. The projected costs of each of the government's three major options were considered to be significantly greater than the projected benefits (Booz, Allen and Hamilton, 1981). The relationship between the results of this study and the closing of the NPRM is evident.

4.2.6.8 Sleep Needs

It is well known in the scientific literature that human performance is best at moderate levels of arousal. At low levels, insufficient energy exists to make informed decisions; at high levels, actions may be frequent, but ill-directed (Allnutt, 1983). Fatigue is typically associated with low levels of arousal, and can be brought on by three categories of stress: (1) physical (e.g., temperature, vibration, etc.); (2) physiological (e.g., drugs and alcohol, irregular eating habits, etc.); and (3) psychological (e.g., fear, frustration, economic pressure, etc.). A distinction is sometimes made between single-trip fatigue, where an opportunity for recovery may exist, cumulative fatigue, in which recovery time between trips is not adequate, and chronic fatigue, which usually requires medical assistance. The behavioral symptoms of all three types of fatigue are similar, however.

Off-duty time as specified in the regulations does not always translate into sleep or rest time as it was intended. This results in part from the manner in which the body functions biologically. Sleep researchers have shown that the body typically functions according to a circadian, or 24 hour, cycle. Thus, when a driver starts his off-duty time, he may not be biologically ready to rest. As an example, a driver who begins a driving day at 6:00 a.m. must stop to rest at 4:00 p.m., according to the regulations. However, his circadian cycle probably is not tuned for him to begin prolonged rest. The driver is likely to take a nap eventually, but will hit the road again at 12:00 midnight, just when his circadian cycle prepares his body for sleep. Military research has shown that no amount of mental or physical conditioning can prepare people to withstand sleep deprivation. The brain will lapse into sleep for seconds at a time, especially under conditions such as driving. Circadian rhythm factors may explain the disproportionate share of accidents that occur in the early morning hours between midnight and 6:00 a.m.

In a survey of truck drivers questioned about drowsiness, approximately 80% reported they had 'slept' or often felt 'drowsy' at the wheel (Endou, et al., 1979). Common misapprehension associates fatigue with the length of time one has been on duty. However, as noted previously, a considerable number of transport accidents occur early into the shift, particularly if the shift began in the early a.m. hours. According to sleep researchers, this is a time when a person is particularly vulnerable because there are three things working against alertness: (1) a low point in the circadian cycle, (2) a low body temperature and metabolic rate, and (3) sleep inertia. With these factors working against alertness, reaction times in this period can double or triple, and sleep researchers actually refer to this time as the "forbidden zone." They argue that a period of decreased alertness also occurs in the mid-afternoon. If driving under the influence, the impairing effects of drugs or alcohol are also greatly augmented in a sleepy person (Dinges, 1987).

There is recent evidence that the assignment of a secondary task can have a beneficial effect on truck driver performance (Drory, 1985). This was most apparent when the secondary task involved voice communication. In this instance, voice communication served as a stimulus without causing a distraction to the basic driving task. Another accident mitigation measure directed at fatigue is the installation of rumble strips on the shoulders of highways to provide an audible warning to inattentive drivers. A California study reported a 49% reduction in "drifted off road" accidents where the strips had been installed (TR News, 1988).

4.2.6.9 On-Board Recording Devices

The use of on-board recording devices as a mechanism for improving compliance with hours of service rules has been proposed by safety advocates. Units are currently available that can evaluate the engine speed, road surface, temperature, tire pressure, oil pressure, cooling system, and other operating elements. Although the information which is collected permits the examination of distance traveled, driving time, breaks, daily rest periods and speed limit compliance, carriers have been purchasing these systems to manage fuel efficiency. One firm reports that an on-board device pays for itself in six months through cost savings in fuel, maintenance and driver time (reduced paperwork requirements). It also serves to streamline the preparation of reports which must be filed regularly with oversight agencies, which has led to DOT accepting recording device output in lieu of logbooks for some carriers. Thus, an economic incentive exists for management of firms for investing in a device that could also be used to enhance safety (OTA, 1988).

This same firm's experience with gaining acceptance from drivers in installing these devices is instructive. First, management held driver seminars to help drivers understand how and why the organization was going to use the recorders. After initial resistance, drivers understood that the recorders provide a mechanism for proving their innocence when a delivery is late because they were following the rules. The system also includes an alarm that activates if a driver runs at speeds greater than 55 mph for more than one minute. If the driver does not reduce speed within a short time period, he is considered to have a speeding violation by the company and can be disciplined. This speed determination capability has made the installation of road speed governors unnecessary (OTA, 1988).

A similar experience with on-board recording devices has been reported by another large transport company. Since the devices were installed, preliminary results show that fuel mileage has already increased by 12%, average drive tire mileage is up to 270,000 miles and brake lining life has increased. Insurance rates have also dropped. To gain acceptance among drivers, the company initiated an incentive plan based on the driver's performance evaluation. From information gathered by the recording device, each driver received a grade based on a cumulative average of all major functions on the trip (e.g., maximum speed, engine revolutions, idle time, etc.). The incentive plan pays drivers an extra 2 cents a mile if they receive a performance grade of 10, and one cent per mile for a grade of 9. Drivers now prefer trucks equipped with the devices so that they can earn extra compensation (Private Line, 1986).

In the courts recently, an insurance case was settled on the basis that the tape from an onboard recording device showed that a truck driver had geared down in anticipation of an automobile driver cutting in front of him to enter a ramp. The truck hit the car, and the driver sued. The device showed that the truck driver did, in fact, gear down, but could not do so fast enough to prevent the accident. The automobile driver lost the case (OTA, 1988).

While several European countries currently require on-board recording devices in their heavy trucks, installation of these devices on trucks in the U.S. remains voluntary although their use is increasing. Several policy questions related to recorders remain unresolved, and the devices still need to have their accuracy and resistance to tampering verified and upgraded. If on-board recording devices were to become mandatory, who would be responsible for enforcing the hours-of-service regulations? Would the onus be on carrier management to monitor the tape and be responsible for compliance? Would FHWA implement a mandatory audit on a regular basis attesting that the carrier reviewed the electronic logs and enforced the regulations? How would such a system work for small carriers and owner-operators?

Tampering has been singled out as a particular concern. Previous research on the effectiveness of technological innovation and the man-machine interface, suggests that if a system design is unacceptable to the user, regardless of engineering performance and reliability, man will underuse it, misuse it, or even sabotage it (Price, 1987).

4.2.6.10 Speeding

Prior analyses indicates that higher speeds are associated with increased accident likelihood and severity. Many common carriers have chosen to limit the speed at which their tractors can be operated through the installation of road speed governors. These devices prevent the engine from generating power in excess of a specified rpm; consequently, unauthorized speeding is curtailed. It is unclear, however, whether this practice has been motivated more by fuel economy savings or a corporate concern for safety. If not tampered with, these devices are quite effective in keeping speed close to the legal limit. However, mandatory speed governors may contribute to driver boredom, an issue that requires further investigation.

Some States, such as Virginia, have tried to control speeding by passing laws outlawing the use of radar detectors. The sole function of a radar detector is to recognize when a law enforcement officer is measuring the vehicle's speed. Therefore, it can be inferred that the prevalence of radar detectors in the trucking industry is an indication of the potential for abusing speed limits. A recent study conducted by IIHS and Goodson Engineering found that radar detectors encourage speeding, with the vehicles traveling fastest being most likely to be equipped with the devices. They also reported that of all vehicles on the road, tractor-trailers are the most likely to be equipped with radar detectors (IIHS, 1987). A recent survey conducted by the Owner-Operators Independent Drivers Association of America indicated that 69% of vehicles driven by owner-operators are equipped with radar detectors. A separate survey of truckers in Florida found that 79% use radar detectors (Regular Common Carrier Conference, 1987).

The use of detectable and non-detectable radar by enforcement officers countered by the use of radar detectors and radar jamming devices by drivers reflects the essence of the relationship between a cost-competitive market and the need to adopt and enforce adequate safety standards. With the vast majority of drivers compensated either by the mile or by the job (Regular Common Carrier Conference, 1987), it is clearly in the driver's economic best interest to make each delivery as quickly as possible.

4.3 HUMAN FACTORS IN RAIL SAFETY

Although relatively little is known about human factors in railroad operations in comparison to the trucking industry, reported findings are remarkably consistent. This information is presented in the following discussion, and is organized according to similar topic headings as in the truck section, wherever possible.

4.3.1 Employee Negligence

An intensive investigation of train accidents in which employee negligence was a primary or contributing factor identified several leading causes of negligence, listed below in order of priority (NTSB, 1972):

1. Disregard of stop signal
2. Excessive speed in other than yard limits
3. Switch improperly aligned
4. Disregard of restricting signal
5. Failure to secure or control by hand brake
6. Absence of man on or at leading car being pushed
7. Excessive speed or failure to control in yard limits
8. Failure to flag
9. Moving without orders or signals
10. Failure to clear switch or other tracks

Each of these items represents human failure in the performance of a function, although they represent different aspects of human involvement. Disregarding signals and yard movement infractions reflect problems of judgment on the part of the engineer, for which back-up mechanisms or procedures are often weak, non-existent or unenforced. Hand brake failures are often attributed to its design and location. Switching problems may be reflective of the lack of cooperation and communication between the engineer and other members of the crew. Irrespective of the specific nature of each failure, NTSB concluded from its study that the employee's attitude is a significant factor in the performance of a safe job.

4.3.2 Drugs and Alcohol

As in the case of the truck industry, it appears that the railroad industry is also plagued by significant drug and alcohol problems.

In 1978, a study of alcohol problems in the railroad industry concluded that roughly 20% of operating employees had either consumed alcohol on the job, come to work affected by it, or suffered from off the job problems that could affect their on-the-job performance (Riley, 1986). Similar findings were reported from autopsies performed on 136 fatally injured railroad employees over a seven-year period. In 16% of the cases, significant levels of alcohol or drugs were present in the bloodstream.

What is disturbing about Federal railroad regulation is that it is inconsistent with other modes with regard to substance abuse. Rail regulations do not specify a pre-duty abstinence period, yet do establish a 0.04 percent blood alcohol limit, and state that operators may not possess or use controlled substances or be impaired by them while on duty (Goldman, 1986). DOT has recently proposed more stringent rulemaking to prohibit the use of controlled substances by any railroad operating employee, whether on-duty or off-duty.

Recent legislation has authorized railroads to test employees for alcohol or drug impairment after accidents or where there is just cause. This is now routinely done for accidents in which there are fatalities, where hazardous material is spilled, and where human performance decrement is a probable cause (Goldman, 1986). This legislation also imposed pre-employment drug screening and created a provision for a railroad employee who has a substance abuse problem to come forward voluntarily, obtain medical treatment, and return to his former position following physician clearance.

One major railroad has experienced significant safety benefits from the implementation of drug and alcohol testing. They reported a 66% decline in human factors accidents over an 18-month period, and lost time injuries declined by over 24%. It is interesting to note that, at the outset, over 23% of employees tested positive, a figure which has declined substantially over time (Dempsey, 1986). Results like these have prompted DOT to propose a rule mandating random drug testing for all railroad employees.

4.3.3 Fatigue

Limited studies of fatigue among railroad operators report results which are entirely consistent with truck fatigue findings. It appears that train operators also suffer from circadian effects (Dinges, 1987).

The most documented findings to date were reported by researchers in West Germany, who studied 2,238 failures by train operators to respond to warning switches. A temporal analysis of these failures revealed two peaks, one at 3:00 a.m. and the other at 2:00 p.m. (Hildebrandt, et al., 1974).

4.3.4 Sharing the Road

Akin to the truck transport problem of big rigs sharing the road with passenger vehicles is the problem of the interaction of trains and passenger cars at grade crossings. An alarming number of serious accidents occur at grade crossings, commonly due to failure of the passenger car to operate safely. Several studies have been conducted examining the safety benefits of improved signage and other warning devices (Koziol and Mengert, 1978).

4.4 HUMAN FACTORS IN MARINE TRANSPORT

The scarcity of literature on human factors in marine transport is reflected in the limited scope of the following discussion.

4.4.1 Drugs and Alcohol

Little has been done to study the scale of the drug and alcohol problem in marine transport. Coast Guard rules prohibit operation of a vessel in a negligent manner while intoxicated. No pre-duty drinking limits are prescribed nor is an intoxication level specified (Goldman, 1986).

DOT has recently proposed a drug testing program for merchant marines that includes pre-employment, post-accident, random, reasonable cause and periodic testing for employees as part of a comprehensive program that also includes education and rehabilitation. Under this program, an estimated 131,700 seamen would be subject to testing, including self-employed vessel operators.

4.4.2 Pilot Performance

Waterway segments where vessel accidents have tended to occur are characterized by the presence of bridges, locks, narrow channel widths, and bends, intersections or junctions (Paramore, et al., 1979). Current has been shown to be the single most frequently cited causal factor in rammings and groundings, and has also been mentioned frequently in collision reports. More specifically, principal task problem areas were found to be imprecise or untimely identification of current force and direction on the mother vessel and/or the tow. Although towboat personnel in particular have limited sources of information and often rely on experience, in general it was found that human error usually arose where improper control decisions and actions were made in situations where there was little margin for error.

5.0 CONCLUSIONS AND POLICY RECOMMENDATIONS

Based on available data and previous studies directed at human factors in transportation, it appears that human factors are likely to be a major cause of radioactive waste transport accidents, both loading and in-transit. Although the consequences of such accidents may be less severe, on the average, with transport accidents caused by other factors, uncertainties in the available accident databases and the public perception of the consequences associated with any radioactive accident suggest that a formal DOE human factors research activity should be initiated.

A review of previous literature and analysis of truck vehicular accident data have constructed a foundation on which to build policy directed at the safe transport of radioactive waste as it relates to human factors. Although most of this work has focused on truck transport, and consequently more detailed policy recommendations can be directed at this mode, based on limited available information, truck, rail and marine transport appear to share some common problems which may require policy intervention.

In terms of container-related areas, these problems focus on securing valves, fittings and closures during the loading process, and making sure they remain snug throughout the in-transit portion of the trip; maintaining internal container pressure within safe limits; safe handling of radioactive materials during the loading process; and proper protection of the shipment from damage should a vehicular accident occur while in-transit.

The human tasks associated with the safe loading and transport of radioactive wastes require personnel who are responsible, qualified, and alert individuals, with a positive attitude towards safety and a level of maturity commensurate with the hazardous nature of the material they are handling. It also requires a carrier management that has made a sincere commitment to safety in its operation, and has made every effort to comply with Federal safety regulation governing the transport of radioactive materials. Finally, it requires a vehicle design and operating environment that extends the margin of error so that when human errors occur, the opportunity to take a corrective action can be made prior to an accident occurrence.

In the discussion to follow, several policy recommendations are made which DOE may wish to consider. In many cases, DOE may not be the agency with jurisdictional purview over the matter, although it would be expected that DOE would work in close cooperation with other agencies to effectuate change where such policy would provide clear safety benefits. It is also important to recognize that these policy recommendations are necessarily general, in keeping with the primary objective of this study as a scoping effort. Those policy areas which DOE would like to investigate more fully should be accompanied by more directed studies in the future.

5.1 POLICY RECOMMENDATIONS

5.1.1 Employee Selection and Hiring Practices

Carriers must be held more accountable for their employee selection and hiring practices. Perhaps DOE should impose standards on prospective carriers of radioactive waste materials concerning the depth of their inquiries with prior employers of job applicants, qualifications of applicants to perform satisfactorily in field test situations, and pre-employment screening of applicants concerning their psychological state to handle the rigors of freight transport operations.

Some help is on the way for the trucking mode with the recent passage of the Commercial Driver's License Program. If the original intent behind this legislation is met in a timely fashion, truck driver licensing practices will become more tightly controlled with uniform standards. However, steps must be taken as part of this process, or as a separate rulemaking initiative, to close loopholes in driver disqualifications for violations occurring while in a non-commercial vehicle, or in part-time or off-duty status.

5.1.2 Drugs and Alcohol

Given the apparent widespread use of drugs and alcohol among truck and rail operating personnel, firm and decisive steps should be taken to respond to this growing problem. Measures such as mandatory drug and alcohol screening for applicants, and for employees as part of their periodic DOT physical examinations deserve consideration. Screening of employees when probable cause can be established is also warranted. Random testing, although it may be effective in practice, must be approached with the legal implications in mind.

There is sufficient evidence that operator performance is impaired at BAC levels well below 0.10. It is recommended that acceptable levels for truck drivers be reduced to 0.04, corresponding to present levels for railroad engineers. This will occur naturally if the DOT Secretary does not make a formal rulemaking by October 1988.

5.1.3 Fatigue

Hours-of-service regulations, formulated well before the introduction of the Interstate highway system, changes in vehicle design and present economic conditions, have become outdated. DOT has been reluctant to set new standards due to potential adverse economic impacts upon carriers. There are compelling reasons for DOT to reexamine the hours-of-service limits and to consider the issuance of new standards which are more consistent with current sleep research results and the present carrier operating environment. Sleep research suggests that an individual's internal 24 hour clock governs human biological performance and behavior, yet the present rules do not consider this factor. However, care must be exercised so that current standards are not replaced with ones that also have loopholes which can be exploited by shippers, owners and operators.

Programs are also needed to help management and drivers understand when drivers are most vulnerable to accidents and how scheduling might be altered to reduce driver vulnerability. A research program to develop simple, effective and inexpensive techniques to screen drivers who may have a sleep disorder could help identify the high (fatigue) risk driver. Moreover, the development of portable performance devices that detect, in a quick, reliable, and non-invasive manner, whether a person is reacting properly is a realistic long-term goal.

However, alertness devices may create an environment of false security. An operator, for instance, can be awakened by such a device, and conclude that he can continue driving since he is now awake. In another situation, the driver could feel tired but decide to continue driving because he could assume that the alertness device would awaken him if he did fall asleep. Drivers and management must understand that the driver remains responsible for driving safely, regardless of the aids installed to help him.

5.1.4 Speeding and Other Moving Violations

On-board recording devices have been demonstrated to be a cost-effective management tool in the trucking industry, leading to fuel economy, maintenance troubleshooting and paperwork reduction. Speed enforcement devices are also available in the railroad industry. The use of on-board recording devices in a truck driver oversight capacity has been successful in the limited applications where this has been attempted. However, in each case, management approached this through a careful and open dialogue with drivers in order to minimize the potential adverse effects of installing these devices. Otherwise, the backlash from employees who have not been properly sensitized may give rise to tampering and abuse.

Consideration should be given to abolishing the use of radar detectors by trucks. These devices serve the single purpose of recognizing when an enforcement officer is measuring the vehicle's speed. Their active use clearly promotes excessive speeding, which has been previously associated with both increasing accident likelihood and severity.

5.1.5 Operator Training

A more active Federal presence in the area of training is urgently needed for truck, rail, and barge operators. In the case of trucking, Federal requirements can be imposed that drivers of heavy trucks graduate from an accredited truck driver training program prior to being eligible for employment consideration. To implement such a policy, however, curriculum standards must be established and a proven accreditation process administered. Considerable progress has been made in this area with DOT proposed curriculum standards and the ongoing efforts of the PTDIA. To be effective, carrier management must also be willing to modify their hiring policy to accept training school graduates without on-the-road experience. Carriers concerned about placing these drivers into the operation without prior experience can develop in-house apprentice programs.

In the case of barge transport, real-time simulation training for towboat navigation warrants serious consideration. Given the narrow safety margins in some domestic waterways and past practices of navigation primarily from experience, navigation training is a rational policy initiative.

5.1.6 Vehicle and Environment Factors

Several aspects of vehicle design and maintenance can be enhanced to provide a greater margin of safety for operators. Braking system, vehicle handling and stability, tire and lighting (reflectorization) improvements would provide beneficial effects on truck safety. Truck occupant protection and alertness can be improved through cab design, and improvements in ride quality (noise, heat, vibration, etc.). Better instrumentation for vessel navigation is needed in barge transport. Brake design and cab warning devices have been suggested as emphasis areas in rail operations.

The operating environment could be enhanced through better cooperation and communication among users who share or interact on a transport facility. Cooperation and communication among railroad crews, between vessels, particularly in blind situations, at railroad-roadway grade crossings, and between trucks and passenger vehicles are emphasis areas. In the case of trucking, for example, this could take the form of education programs directed at creating an awareness of the handling and stability characteristics of trucks as well as the potential for severe damage that can be administered by truck mass in crash situations. It also suggests the importance of using escort vehicles for radioactive waste shipments.

5.1.7 Enforcement

For any current and proposed standards to be effective, they require considerable public and private enforcement effort.

Government programs, such as MCSAP, are exemplary in terms of their effectiveness in identifying vehicle defects and some driver violations, and plans are underway to extend this oversight to audits of carriers and personnel practices at freight terminals. In many respects, however, this is a small portion of a much larger problem associated with ensuring compliance with Federal regulation. Quite frankly, without adequate enforcement, the intent of safety standards will not be met and may as well not be there at all.

To meet these growing requirements, it is likely that additional inspectors will be needed. Increases in the penalties for non-compliance may also serve as encouragement to abide by operating rules.

Cooperation of carriers is also essential to the safety equation. Carrier management must adopt a company-wide commitment to safety. This should be conveyed to everyone in the organization as an inherent attitude around which performance is evaluated. In addition to applying internally to drivers and dispatchers, this philosophy must be transmitted to shippers and brokers. With all these parties involved, the likelihood of a safer operating environment will be considerably enhanced.

6.0 REFERENCES

Allnutt, M., 1983. "Human Factors: Basic Principles," in Pilot Error, The Human Factors, edited by R. Hurst and L. Hurst, Granada Publishing.

Anderson, A., et al.., 1980. "Injuries in Trucks and the Effectiveness of Seat Belts," Proceedings of the 24th Conference of the American Association of Automotive Medicine.

Beilock, R., 1987. 1986 Motor Carrier Safety Survey, Regular Common Carrier Conference.

Booz, Allen and Hamilton, Inc., 1981. Assessment of the Impacts of Proposed Hours of Service Revisions, prepared for OMC, Report No. DTFH61-80-C-00088.

Borzo, G., 1987. "Motor Carriers Institute Pre-Employment Drug Tests," Traffic World, June 15, 1987, p. 12.

Bureau of Motor Carrier Safety, 1979. 1976-1978 Analysis of Motor Carrier Accidents Involving Vehicle Defects or Mechanical Failure.

California Highway Patrol, 1987. Joint Legislative Report on Truck Safety, Report No. AB-2678.

California Highway Patrol, 1976. Critical Item Inspection Fact Sheet.

Carsten, O., 1987. "U.S. Accident Experience of Single and Double Trailer Combinations," Symposium on the Role of Heavy Freight Vehicles in Traffic Accidents, OECD, Vol. 1, p. 2-80.

Chow, G., 1987. "Deregulation, Financial Condition and Safety in the General Freight Trucking Industry," presented at the Northwestern University Conference on Economic Regulation and Safety.

Dempsey, William, 1986. President, Association of American Railroads, Testimony before the Committee on Commerce, Science and Transportation, U.S. Senate, February 18, 1986.

Dinges, David, 1987. Testimony before the Subcommittee on Transportation, Committee on Appropriations, U.S. Senate, May 14, 1987.

Drew, G.C., W.P. Colguhoun and H.A. Long, 1959. Effect of Small Doses of Alcohol on a Skill Resembling Driving, Her Majesty's Stationary Office, London.

Drory, A., 1985. "Effects of Rest and Secondary Task on Simulated Truck-Driving Task Performance," Human Factors, Vol. 27, No. 2, pp. 201-207.

Endou, T., M. Ohshima, T. Watanabe and O. Shingo, 1979. "A Preventive Measure Against Drowsiness While Driving," Ergonomics, Vol. 22, No. 6, p. 758.

Federal Highway Administration, 1987. Monitoring Operations of Larger Dimension Vehicles, January 14 report.

Fructus, J., 1987. "Highlights on Heavy Vehicle Safety in Europe," Symposium on the Role of Heavy Freight Vehicles in Traffic Accidents, OECD, Vol. 1, p. 1-31.

General Services Administration, 1984. Code of Federal Regulations - Transportation, 49, Parts 100 to 177, U.S. Government Printing Office.

Goldman, P., 1986. Vice Chairman, NTSB, Testimony before the Committee on Commerce, Science and Transportation, U.S. Senate, February 18, 1986.

Green, P., et al.., 1980. Accidents and the Nighttime Conspicuity of Trucks, University of Michigan.

Hackman, K.D., et al.., 1978. Analysis of Accident Data and Hours of Service of Interstate Commercial Motor Vehicle Drivers, prepared for the Federal Highway Administration.

Hamelin, P., 1987. "Truck Drivers' Involvement in Traffic Accidents as Related to their Shiftworks and Professional Features." Symposium on the Role of Heavy Freight Vehicles in Traffic Accidents, OECD, Vol. 2.

Harris, W. and R.R. Mackie, 1972. A Study of the Relationships Among Fatigue, Hours of Service, and Safety of Operations of Truck and Bus Drivers, Human Factors Research, Inc.

Hildebrandt, G., W. Rohmert and J. Rutenfranz, 1974. "12 and 24 Hour Rhythms in Error Frequency of Locomotive Drivers and the Influence of Tiredness," International Journal of Chronobiology, Vol. 2, p. 175-180.

Insurance Institute for Highway Safety, 1987. "Radar Detectors Spur Speeding," IIHS Status Report, Vol. 22, No. 3.

Insurance Institute for Highway Safety, 1985. Big Trucks.

Jones, I.S. and H.S. Stein, 1988. "Truck Operating Characteristics in Relation to Safety," ASCE Truck Safety Conference.

Jovanis, P.O., 1987. "A Perspective on Motor Carrier Safety Issues in the 1980's," presented at the Conference on Truck Safety, Northwestern University.

Karlson, T., et al.., 1977. "Fatally Injured Truck Drivers," Proceedings of the 21st Conference of the American Association of Automotive Medicine.

Koziol, J.S. and P.H. Mengert, 1978. Railroad Grade Crossing Passive Signing Study, Report No. FHWA-RD-78-34.

Landis, R., 1986. Associate Administrator for Motor Carriers, Testimony before the Committee on Commerce, Science and Transportation, U.S. Senate, February 18, 1986.

Lees, I.J., 1987. "Nature and Cause of Heavy Freight Vehicle Crashes in Australia," Symposium on the Role of Heavy Freight Vehicles in Traffic Accidents, OECD, Vol. 1, p. 2-57.

Lipping, H., 1980. Traffic as Working Environment, Transportation Vaestra Vaegen, Sweden.

Mackie, R.R. and J.C. Miller, 1978. Effects of Hours of Service, Regularity of Schedules and Cargo Loading on Truck and Bus Driver Fatigue, Human Factors Research, Inc.

Motor Vehicle Manufacturer's Association, 1985. Motor Truck Research.

National Highway Traffic Safety Administration, 1987. Heavy Truck Safety Study, prepared in response to Motor Carrier Safety Act of 1984.

National Highway Traffic Safety Administration, 1986. Truck Occupant Protection, prepared in response to Motor Carrier Safety Act of 1984.

National Highway Traffic Safety Administration, 1981a. National Accident Sampling System (NASS), Analytical User's Manual.

National Highway Traffic Safety Administration, 1981b. Fatal Accident Reporting Systems (FARS), User's Guide.

National Transportation Safety Board, 1987. NTSB Heavy Truck Study, presented at the National Motor Carrier Safety Workshop.

National Transportation Safety Board, 1986. Training, Licensing and Qualification Standards for Drivers of Heavy Trucks, Report No. DB86-917001.

National Transportation Safety Board, 1972. Special Study of Train Accidents Attributed to the "Negligence of Employees."

Office of Technology Assessment, U.S. Congress, 1988. Gearing Up for Safety: Motor Carrier Safety in a Competitive Environment.

Office of Technology Assessment, U.S. Congress, 1986. Transportation of Hazardous Materials, OTA-SET-304, U.S. Government Printing Office.

Olson, P.D., et al., 1984. Parameters Affecting Stopping Sight Distance, NCHRP Report No. 270, prepared for the Transportation Research Board.

Oregon Public Utility Commissioner, 1985. 1984 Truck Inspections and Truck Accidents in Oregon.

Paramore, et al., 1979. Human and Physical Factors Affecting Collisions, Rammings, and Groundings on Western Rivers and Gulf Intercoastal Waterways, prepared by ORI, Inc. for the U.S. Coast Guard.

Price, H.E., 1987. "Technology and the Man-Machine Interface Effectiveness," presented at the Man-Machine Interface Workshop, Windsor, Ontario.

Private Line, 1986. "A Driver Incentive Plan with an On-Board Computer Rewards Proper Vehicle Operation," October, p. 15.

Ranney, T.A., K. Perchonok and L.E. Pollack, 1984. Identification and Testing of Countermeasures for Specific Alcohol Accident Types and Problems - Volume III: The Heavy Truck Alcohol Problem. Prepared for NHTSA, Report No. HS-806-651.

Regular Common Carrier Conference, 1987. RCCC Motor Carrier Safety Survey, Alexandria, VA.

Reif, Z.F., T.N. Moore, and A.E. Steevensz, 1980. Noise Exposure of Truck Drivers, Society of Automotive Engineers, Report No. SAE 800278.

Riley, J., 1986. Administrator for the Federal Railroad Administration, Testimony before the Committee on Commerce, Science and Transportation, U.S. Senate, February 18, 1986.

Robinson, H., et al., 1969. Trucks in Rural Injury Accidents, prepared for NHTSA, Report No. HS-800-232.

Safety Management Institute, 1978. Analysis of Accident Data and Hours of Service of Interstate Commercial Motor Vehicle Drivers, prepared for OMC.

Sanders, M.J., 1980. A Nationwide Survey of Truck and Bus Drivers, Canyon Research Group, Inc.

Sheridan, T., 1983. "Measuring, Modeling and Augmenting Reliability in Man-Machine Systems," Automatica, 19(6), 637-645.

Solomon, D., 1964. Accidents on Main Rural Highways Related to Speed, Driver and Vehicle, U.S. Department of Commerce, Bureau of Public Roads.

Stocker, I.U., 1987. "Statistical Analysis of HFV Accidents," Symposium on the Role of Heavy Freight Vehicles in Traffic Accidents, OECD, Vol. 1, p. 2-16.

Strandberg, L., 1987. "On the Braking Safety of Articulated Heavy Freight Vehicles," Symposium on the Role of Heavy Freight Vehicles in Traffic Accidents, OECD, Vol. 2, p. 3-28.

Theis, T., 1987. "Road Freight Transport Related Aspects Resulting from Deregulatory Actions Within the European Communities: Consequences in the Special Field of Road Safety," Symposium on the Role of Heavy Freight Vehicles in Traffic Accidents, OECD, Vol. 3, p. 4-38.

TR News, 1988. "Rumble Strips Alert Drivers, Save Lives and Money," Transportation Research Board, March-April Issue, pp. 20-21.

Transportation Research Board, 1987. Zero Alcohol and Other Options: Limits for Truck and Bus Drivers, Special Report 216.

Troup, J.D.G., 1978. "Driver's Back Pain and Its Prevention: A Review of the Postural, Vibratory and Muscular Factors, Together With the Problem of Transmitted Road-Shock," Applied Ergonomics, Vol. 9, No. 4, pp. 207-214.

Tuler, Seth, R.E. Kasperson and S. Ratick, 1988. The Effects of Human Reliability on Risk in the Transportation of Spent Nuclear Fuel, draft final report, prepared by Clark University for the Nevada Nuclear Waste Project Office.

U.S. Coast Guard, 1984. Coding Instructions for the Automated File of Commercial Vessel Casualties.

Wilson, L.J. and T.W. Horner, 1979. Data Analysis of Tractor-Trailer Drivers to Assess Drivers' Perception of Heavy Duty Truck Ride Quality, prepared for NHTSA, Report No. DOT-HS-805-139.

Winkler, C., et al.., 1983. Parametric Analysis of Heavy Duty Truck Dynamic Stability, prepared for the National Highway Traffic Safety Administration.

Winsor, Jim, 1987. "Serious Accidents: Manpower Shortages vs. Driver Quality," Heavy Duty Trucking, July, p. 18.

Wyckoff, D.D., 1979. Truck Drivers in America, Lexington Books.

Ziskind, R., T. Carlin, M. Axelrod, R.W. Allen and S.H. Schwartz, 1977. Toxic Gases in Heavy Duty Diesel Truck Cabs, prepared for U.S. DOT, Report No. FHWA-RD-77-139.

APPENDIX A

HAZARDOUS MATERIALS TRANSPORTATION INCIDENT/ACCIDENT INFORMATION SYSTEMS

A.1 INTRODUCTION

As concern over the safe transport of hazardous materials continues to grow, public officials are placing greater emphasis on the ability to conduct analyses of present practices and future policy initiatives. The capability to do this effectively is directly dependent on the quality and availability of information on previous transport accidents and incidents involving hazardous materials cargo.

The objective of this appendix is to explore the reporting requirements of hazardous material transport accidents and incidents, and to determine what use is and can be made of the information which is collected and stored. As described herein, hazardous materials are defined by statute (Hazardous Materials Transportation Act) and by regulation (49 CFR 171.8) as substances and materials in quantities and forms that the Secretary of Transportation has found may pose an unreasonable risk to health and safety, or to property, when transported in commerce (General Services Administration, 1984). The approximately 2,400 materials classified as such are listed in 49 CFR 172 (Transportation Research Board, 1983).

Inclusive in this list are several substances and wastes classified as "hazardous" in order to coordinate DOT's regulatory program with that of the Environmental Protection Agency (EPA). The primary reason for designating these materials is their long-term effects on health and the environment (National Conference of State Legislatures, 1984). For each substance, EPA has established a "reportable quantity" (RQ) which indicates the quantity and concentration of a chemical that could pose a threat of pollution. RQ's for most substances are one pound, although EPA has recently studied the effects of changing the RQ level (ICF, 1985). Packages containing more than the RQ of the hazardous substance are subject to DOT regulation. DOT regulations also apply to hazardous wastes that are subject to EPA's manifest system under the Resource Conservation and Recovery Act (RCRA).

To carry out the regulatory requirements imposed by the Hazardous Materials Transportation Act (HMTA), the Secretary of Transportation established the Office of Hazardous Materials Transport (OHMT), which was formerly known as the Materials Transportation Bureau. OHMT is responsible for regulating hazardous materials transport safety, including all transportation by water, which is promulgated by the U.S. Coast Guard under 46 USC 170 and 391(a). OHMT's responsibilities also include coordination among the various DOT modal administrations and other Federal agencies which are involved in the transport of hazardous materials.

The source of data for analyzing hazardous material incidents emanates from the reports filed by carriers and others responsible for reporting to various agencies under Federal regulations. Each database potentially applicable to study hazardous materials transport safety is described separately in the following discussion. A table listing these information sources and their relationship appears in the main body of this report.

A.2 OHMT HAZARDOUS MATERIAL INCIDENT REPORTS (HMIS)

This database became the centralized Federal system for uniform incident data in 1971. Prior to that time, hazardous materials regulatory authority was divided among the DOT modal administrations. Each agency independently developed criteria reflecting their particular needs for data collection and analysis. A wide range of hazardous materials reporting systems evolved which resulted in redundant reporting, inconsistencies in definition and coverage, and reporting gaps.

A transportation-related incident is defined as any unintentional release of a hazardous material during transportation, or during loading/unloading or temporary storage related to transportation. This includes releases of hazardous wastes and reportable quantities of hazardous substances discharged during transport (Materials Transportation Bureau, 1980). Every incident must be reported to OHMT in writing as prescribed in the 49 CFR regulations (Parts 171, 174-177), with the exception of consumer commodities which present only a limited hazard during transportation (ORM-D class), electric storage batteries, and certain paints and related materials (General Services Administration, 1984). These exceptions were established in 1981, and have decreased the number of reported incidents considerably. The exceptions, however, do not apply to incidents involving aircraft or those involving the transport of hazardous waste. The written response must be prepared by the carrier on Form F5800.1 and must be submitted to OHMT within 15 days of discovery of the release (USDOT, 1983). While carriers are required to report, any interested party may report.

An additional telephone reporting requirement is imposed on carriers when an incident has resulted in one or more of the following consequences as a direct result of the hazardous material (General Services Administration, 1984):

1. a fatality
2. a serious injury which requires hospitalization
3. estimated carrier or other property damage exceeds $50,000
4. fire, breakage or suspected radioactive contamination occurs involving shipment of radioactive material
5. fire, breakage or suspected contamination occurs involving shipment of etiologic agents
6. a situation exists of such a nature that, in the judgement of the carrier, it should be reported.

The telephone report must be communicated immediately to the National Response Center (NRC), a center staffed 24 hours a day by the U.S. Coast Guard, but which handles the reporting of all significant hazardous materials spills under agreements with DOT and EPA. The National Response Center, established in 1974, provides facilities, communication, information storage and other needs for coordinating emergency response. NRC has two 24-hour toll-free telephone lines to receive the notifications, and several other lines to relay the calls to response agencies that may need to know of the release.

The telephone report must include the following information:

1. name of reporter
2. name and address of carrier represented by the reporter

3. phone number where the reporter can be contacted
4. date, time and location of the incident
5. the extent of injuries, if any
6. classification name, and quantities of hazardous materials involved, if such information is available
7. type of incident and nature of hazardous material involvement, and whether a continuing danger to life exists at the scene.

This information is transmitted to the U.S. DOT-Transportation Systems Center every evening, where it is subsequently retained and managed by OHMT.

In many cases, carriers have made their telephone contact with CHEMTREC, a chemical transportation emergency center established in 1971 by the Chemical Manufacturers Association. Upon request, CHEMTREC provides referrals to persons at the site of a transportation emergency involving hazardous materials. Since 1980, CHEMTREC has been officially required to notify the NRC of "significant" hazardous materials transportation incidents, those which have, or have the potential for, causing considerable harm to the public or the environment. Despite this cooperative arrangement, a call to CHEMTREC only fulfills the NRC telephone reporting requirements, but it does not fulfill the Federal written reporting requirements.

Although spill reporting is a regulatory requirement, in practice it is handled on a voluntary basis. The incentive for reporting is to avoid the possibility of a civil penalty, or a criminal penalty which can be imposed if a person knowingly commits an act that violates an HMTA regulation. Civil penalties, which are more common than criminal penalties, can include a liability of up to $10,000 per violation, or one year imprisonment, or both. Criminal penalties are subject to a fine of up to $25,000 or five years imprisonment, or both.

However, since OHMT has very few inspectors to assure compliance with these reporting requirements, and there is a general shortage of inspectors within the DOT modal administrations, it is basically agreed that the Federal enforcement program does not by itself create an adequate deterrent to reporting violations. It has also been suggested that, even when violaters are penalized, the level of the penalty is insufficient to deter future violations. The reason is that the costs of compliance are greater than those of the infrequent penalties. Thus, some operators may consider penalties to be merely an occasional cost of doing business (National Conference of State Legislatures, 1984).

In support of this claim, a recent study conducted by the U.S. Congress, Office of Technology Assessment (OTA) has found that up to and perhaps more than 30-40% of reportable hazardous material incidents are never reported (Abkowitz and List, 1986). EPA Region 7 officials have independently estimated that only about 10% of reportable releases under 100 gallons are reported to EPA, the states or the National Response Center, if the substance released is not extremely hazardous; if somebody spilled five gallons of an extremely hazardous substance, it would probably be reported; 90% of releases over 100 gallons are reported; and 20% of all PCB releases are reported (ICF, 1985). Transport-related incidents constitute 26% of the incident reports compiled by EPA.

This information system has also been the subject of considerable criticism from the U.S. General Accounting Office for the following reasons (General Services Administration, 1984):

1. OHMT is not receiving reports on all incidents because it relies on voluntary reporting from carriers.
2. Companies involved only in the loading, unloading or storage of hazardous materials (e.g., shippers, freight forwarders) are not required to submit hazardous material incident reports.
3. Reports are not required by OHMT for incidents involving hazardous materials shipped in bulk by water.
4. DOT has elected not to regulate firms involved only in intrastate transportation, or require them to submit hazardous materials incident reports.
5. OHMT has no systematic procedure for refining reported data which are incomplete or inaccurate.
6. Due to the time limit on reporting and by soliciting solely the carrier's perspective, the total consequence of an incident can be understated significantly.

Each of these factors works to understate the overall impact of hazardous materials transportation incidents in the United States.

Illustrations of these disparities are noted by GAO and other studies. The GAO selected 30 hazardous material transport incidents between 1976 and 1979 and requested OHMT data on these incidents. OHMT had received reports on only 12 of these incidents. The 18 unreported incidents, according to news reports, resulted in 18 deaths, 9 missing persons, and at least 187 injuries. Concerning damage estimates, NTSB investigations of five accidents involving the transport of hazardous materials between 1972 and 1979 estimated the overall damage to be $42 million, as compared to an estimate of $10.1 million from OHMT reports (Scanlon, 1983). A more detailed study on non-reporting and mis-reporting conducted by OTA has substantiated these claims (Abkowitz and List, 1986).

Despite the objections to the HMIS database, in many respects it serves as the most relevant database for conducting hazardous materials transport incident and safety analysis. The HMIS database is the only on exclusively devoted to hazardous materials transport incidents, and as such, it includes a number of descriptors which can be used to examine issues in packaging, labeling, cause and public safety, that might not otherwise be possible.

If the deficiencies in the database are accepted as stated, the total volume of hazardous materials incidents is underestimated. However, for the purposes of deriving distributions of events, causes and consequences, and for some multi-modal comparative analyses, the HMIS database may still be representative. The approximately 135,000 records which now comprise the HMIR database may permit comprehensive analysis based on statistical considerations.

A.3 SUPPLEMENTARY DATABASES

Independent of the OHMT incident reporting system are several accident reporting systems maintained by various DOT modal administrations. The term "accident" refers to a vehicular accident; most hazardous materials transport incidents are not caused by vehicular accidents (e.g., loose fitting). These reporting systems have been designed to cover all transportation accidents under the jurisdiction of the respective modal administrations, not just those involving hazardous materials. In most cases, however, there are special identifiers in the reporting format to permit the designation of an accident that involves hazardous cargo. This may be a particularly important form of secondary data, as the accident reports are usually based on an independent set of reporting procedures from the OHMT procedures, and thus are not subject to the same deficiencies as noted in the OHMT information system.

Several sources of information outside of DOT also exist which, in some fashion, address the subject of incidents and accidents involving the transportation of hazardous materials.

A.3.1 Modal Administrations

In addition to coordinating activities with OHMT, the DOT modal administrations conduct their own recordkeeping procedures for accidents under their purview. In many cases, the capability exists to isolate accidents which involve the transport of hazardous materials.

A.3.1.1 U.S. Coast Guard

The Coast Guard maintains two databases which include recognition of accidents and/or incidents involving hazardous materials: (1) Commercial Vessel Casualty File (CVCF), and (2) Pollution Incident Reporting System (PIRS).

The Commercial Vessel Casualty File includes vessel accidents (domestic and foreign) occurring in U.S. waters which meet one or more of the following reporting criteria:

1. actual physical damage to property in excess of $25,000
2. material damage affecting the seaworthiness, maneuverability or efficiency of a vessel
3. stranding or grounding (with or without damage)
4. loss of life
5. injury causing any person to remain incapacitated for a period in excess of 72 hours, except injury to harbor workers not resulting in death and not resulting from vessel casualty or vessel equipment casualty.

This data has been collected since 1963, and the only major reporting changes have been a move to an alphanumeric format in 1980, and a change in the damage threshold in August 1982 from $1,500 to $25,000. Fields in each record include vessel characteristics, event, cause, fatalities/injuries and monetary damage. The major deficiency in the file is the lack of a commodity classification in the database. However, there are specific vessel codes which indicate whether the vessel was carrying hazardous cargo (U.S. Coast Guard, 1984).

The PIRS database consists of reports generated as required by FWPCA and CERCLA. It includes all polluting spills into U.S. waters, including those occurring during transport. There is a special identification for transport-related spills and materials are identified by name, so hazardous substance spills during transport can be tracked. The database also includes the quantity released, cause of the incident, and the date and location. In addition, the file contains potential incidents where the Coast Guard was called in, but a spill did not materialize (U.S. Coast Guard, 1983).

According to Coast Guard officials, the PIRS database is rather unreliable, owing to unedited files where major errors often appear. Furthermore, only closed cases are available for analysis from the database, so recent cases, those which are tied up in the courts, and cases where the Coast Guard district has neglected to update the file when a case is closed, are not available and bias any conclusions reached by using the data. The Coast Guard is in the process of designing methods to address these problems.

The Coast Guard databases may be viewed as filling a rather glaring gap in the HMIS database, which is particularly weak in the marine mode. This is due, in part, to the lack of OHMT regulatory enforcement of bulk movements shipped by water.

A.3.1.2 Federal Highway Administration (FHWA)

FHWA's Office of Motor Carriers (OMC) maintains a database on accidents which has been operational since 1973. It includes any motor carrier accident in which a fatality or injury occurred, or for which there was at least $2,000 in property damage. Reports are filed on Form 50-T, the format of which has remained relatively stable through the years. The OMC database includes carrier identification and address, location of the incident, characteristics of the event, cause, information on the cargo, and consequences of the accident. The carrier identification, cargo description and certain accident characteristics are such that congruence between the HMIS database and OMC database may be achievable for incidents caused by vehicular accidents.

A.3.1.3 Federal Railroad Administration (FRA)

FRA maintains its own accident/incident database from information generated by railroads, inspectors and OHMT. Although the database goes back before 1974, access to the pre-1974 data is rather difficult. The database includes information similar to the accident characteristics described in the Coast Guard and FHWA databases. FRA has its own definition of incidents and accidents. An incident is an event which results in a death, reportable injury or property damage. If the event results in a death or reportable injury, <u>and</u> damages exceed a threshold of $4,900, then the event is classified as an accident. The threshold value has been increased by FRA over the years to approximate constant real value.

FRA performs a number of internal consistency checks to strengthen the validity of the database. These include the elimination of double-counting of events when more than one railroad files a report, spot checks of suspicious events and occasional audits of railroad internal records.

In the past ten years, over 80,000 records have been included in the FRA file. Approximately 1,000 of these have involved releases of hazardous materials.

FRA also maintains an OHMT enhanced database on hazardous materials incidents. The enhancements include the addition of accident location information, railroad code and STCC code.*

A.3.1.4 Federal Aviation Administration (FAA)

The FAA maintains a computerized accident/incident database at their National Field Office in Oklahoma City which consists of air accidents officially reported to NTSB and reports filed by FAA field inspectors. FAA makes a distinction between an "accident" and an "incident" based on the dollar damage incurred in the reported event. The FAA database includes the pilot involved, the carrier, time-of-day, and other descriptors such as contributing circumstances and accident (incident) severity. It is apparently possible to identify hazardous materials accidents/incidents in this database, for according to FAA officials, 11 accidents/incidents involving hazardous materials have been reported in the past five years.

A.3.1.5 National Highway Traffic Safety Administration (NHTSA)

NHTSA's National Center for Statistics and Analysis maintains accident data on police reported accidents, including those which resulted in non-fatal injury and/or property damage. The data is typically collected by each state under contractual agreement with NHTSA.

The file of reported accidents is called the National Accident Sampling System (NASS). NASS was developed to provide an automated, comprehensive national traffic accident database. The accidents investigated in NASS are a probability sample of all police-reported accidents in the U.S. (NHTSA, 1981a). The data collection for a NASS-selected accident is very involved, and includes characteristics of the accident, driver, occupants, and vehicle. Although the specific commodity being carried is not described, sufficient information exists to track accidents which are likely to have contained hazardous materials cargo. In fact, recently a hazardous materials "flag" has been added to the record description. However, outside of the date and location of the accident, there appears to be little or no congruence with the data collected by OHMT. Even so, the characteristics of the driver, road and traffic may be important determinants of hazardous materials accidents for which OHMT does not have the appropriate information.

Those accidents which result in loss of human life are also classified separately in the Fatal Accident Reporting System (FARS). The FARS file contains data on vehicles and persons involved in fatal accidents, defined as an event in which an accident-related death occurred within 30 days of the accident (NHTSA, 1981b). FARS is not a national sample; rather, it includes all fatal traffic accidents that are reported in the United States. Other than this distinction, however, the information collected parallels the NASS data structure and is subject to the same critique as noted previously.

* Standard Transportation Commodity Code

A.3.2 Other Useful Databases

The following information systems may also be useful in analyzing hazardous materials transport safety. They consist of other Federal agencies state and local agencies, carriers and trade organizations that maintain data on accidents and incidents.

A.3.2.1 National Response Center (NRC)

Although telephone reports to the National Response Center are primarily intended to stimulate a response action, the information provided in these reports can be used for policy analysis. Data items include the location of the incident, mode of transportation involved, material involved, and quantity released. The material definitions are coded differently than in the HMIS and causal factors are not considered in any fashion. However, the NRC database does provide a more balanced portfolio of incidents by various modes, particularly with regard to marine transport.

A.3.2.2 Environmental Protection Agency

EPA regional offices have personnel to receive notification of releases of hazardous substances. These notifications are integrated into a regional incident reporting system. Typical reports include the incident date, company involved, spill location, nature of the emergency, material spilled and volume, source of the spill, responding agency, nature of the response and resolution. In some EPA regions, this information is maintained in computerized files.

EPA also receives the NRC reports and uses this information in concert with incidents reported to EPA regional offices, states and local governments to formulate regulatory policy. Attempts are presently being made to use the NRC reports as a management information system to support EPA initiatives.

A.3.2.3 National Transportation Safety Board (NTSB)

NTSB receives the NRC telephone reports, which they use in determining whether to proceed with an investigation. NTSB's investigation of transportation accidents is a multi-modal activity. Their jurisdiction for conducting investigation is based on the definition of a major vehicular accident as defined by each mode in CFR 49.

An NTSB investigation begins with a multiple-day field investigation involving the shipper, carrier, government agencies, associations, and other interested parties. A report is subsequently generated which goes through several cycles of review and comment before it is finalized. The primary purpose of the report is to make recommendations to improve transportation safety based on findings from the accident investigation.

A major advantage of the NTSB process is that the investigations involve other participants besides the carrier, are extremely thorough, and take place over a longer time frame so that the full impact of the accident can be more accurately identified. As noted by GAO in their critique of the HMIS database, the damages reported by the carrier to OHMT often substantially underestimate those reported by NTSB (U.S. GAO, 1980).

NTSB does maintain a database on the vital statistics of each investigated accident. Railroad and aviation accidents are stored in computer files. Highway and marine accidents are stored on coding sheets, but have not, as yet, been logged into the computer system.

A.3.2.4 Department of Energy (DOE)

DOE maintains a database on all radioactive incidents, known as the Radioactive Materials Incident Reports (RMIR), based on the HMIS file and information from the Nuclear Regulatory Commission on the loss of control of radioactives. The database consists of approximately 70% HMIS records and 30% Nuclear Regulatory Commission records. It is on-line, and is maintained by Sandia Labs.

A.3.2.5 Nuclear Regulatory Commission

Besides the aforementioned activity, the Nuclear Regulatory Commission is the lead agency in conducting investigations of transport accidents involving radioactive materials. These investigations have focused on mechanical analyses of the containers involved in the accident, for the purpose of improving the safety of containers used in transporting radioactive materials.

A.3.2.6 State and Local Agencies

Accident/incident databases maintained by state and local agencies vary considerably depending on the authorities involved and the level of commitment that has been made to managing the hazardous materials transport problem.

Based on limited observation, state and local agencies appear to be more directly involved in accident reporting systems than incident reporting systems and focus much of their attention on the highway mode. This likely is due to the role of the state and local police in reporting traffic accidents, and a more established and coordinated network of accident management. Some states do, however, have mandatory reporting of hazardous substance releases similar to CERCLA requirements although many local agencies are unaware of these reporting requirements (National Conference of State Legislatures, 1984).

There have, however, been state and local attempts to focus on hazardous materials incidents. Much of this activity has been funded by OHMT in the form of demonstration projects to examine hazardous materials accident prevention and emergency response capabilities.

The first of these projects, completed in 1981, was conducted by the Puget Sound Council of Governments (PSCOG). As part of its study, PSCOG examined hazardous materials movements and incidents within the region. Subsequent projects have been conducted by the State of Massachusetts, the cities of New Orleans, Memphis and Indianapolis, the Association of Bay Area Governments (San Francisco), and Niagara County, New York. While the grantees have, in some cases, made efforts to collect incident data from local sources, often the HMIS database has been accessed to identify incidents which have occurred in the study region (City of Indianapolis, 1983).

More sophisticated applications at the state level center around the use of computerized accident recordkeeping systems in concert with flow data to determine accident rates and high risk locations in the highway network. The states of Utah, Washington and New York, for example, maintain computerized accident recordkeeping databases that contain police accident investigation reports. Typically, these reports include, when a heavy-truck is involved, the carrier name, vehicle type, contributing circumstances, accident severity, etc. In the case of the state of Washington, the type of cargo (United National Code) is also included.

This type of database permits the extraction of heavy vehicle accidents where hazardous cargo was involved (or likely was involved). This information can be portrayed against movement data to determine accident rates of vehicles transporting hazardous cargo, which can subsequently be used in the computation of transport risk profiles and the identification of safer procedures for routing hazardous materials. Although the capability to do this exists in the states of Washington and New York, the fragmented nature of where accident and movement data reside, and their relationship with the offices responsible for policy analysis have served as constraints. These states are, however, moving in the direction of conducting improved analyses with the data that is collected and maintained.

The State of Maryland has largely overcome these problems. Several years ago, Maryland began a surveillance system of hazardous cargo movements at multiple check points and different times of the day. It also instituted a state incident reporting system where any hazardous material incident resulting in a reported spill is entered into the database. These two sources of information are subsequently compared to determine the level of hazardous material transport safety in the state. This information has been used to successfully demonstrate a preferred nuclear materials routing system in Maryland. It should be noted that the accomplishments in Maryland have come after ten years of activity and significant coordination among state agencies.

A.3.2.7 Carriers

Virtually all carriers retain copies of reports on accidents and incidents that they have filed with the appropriate authorities. However, personal contact with a few carriers has shown that the method used for reporting information on Form F5800.1 is rather arbitrary. For example, if the damage is rather small, it is often reported as no damage. Furthermore, when the damage is measurable, the carriers usually report the out-of-pocket cost, and often include only the loss of cargo and not the clean-up cost.

In fact, beyond the reporting requirement to OHMT, there is little evidence that the incident reports are used internally for any analysis purposes, including the safety of operations. The carriers who were contacted also indicated that the 15 day reporting requirement is too short and that is inappropriate for the carrier to assume the reporting requirement for loading/unloading incidents since they do not perform this function and often are unaware of the incident having occurred or the details concerning it.

A.3.2.8 Association of American Railroads (AAR)

The AAR maintains its own hazardous materials incident database from inspector, railroad, F5800.1, CHEMTREC and telephone reports. Information includes date, incident location, incident type, source of the data, deaths and injuries, and estimated damage. The damage estimates can be segmented by equipment, lading, fire and other damage. The AAR database goes back to 1973.

A.4 REGULATORY USES OF THE DATABASES

The previously described databases serve a very important purpose for DOT, its modal administrations, and other agencies in the areas of inspection, enforcement and equipment requirements.

The size of the hazardous materials regulated community is such that inspection of every facility, manufacturer, shipper, carrier, etc., is infeasible, requiring modal administrations to use a variety of criteria to determine how best to deploy their finite inspection resources. As a rule, violation and incident experience are the indicators most frequently used to identify areas on which to concentrate their inspection efforts. The Coast Guard, for example, has redirected its inspection efforts towards "high-priority" vessels, the definition of which includes a vessel with a previously reported hazardous materials incident. OMC and FRA also use selection criteria to determine inspection priorities which are based in part on incident experience (USDOT, 1983).

Statistics generated by the hazardous materials incident databases are also used internally to measure program effectiveness, improve prevention by identifying and analyzing causes and events, and for general regulatory and enforcement analysis. For example, OHMT is interested in the data for regulatory evaluation concerning packaging requirements. OMC uses its database for cargo container analyses. In the case of the railroad industry, DOT has used incident/accident data to examine container specifications for tank cars. This resulted in amendments to CFR 49 that require thermal protection or insulation against external fire sources, tank-head protection against punctures, coupler modifications to resist disengagement, and other improvements to be made to new cars or retrofitted to existing equipment used to transport hazardous chemicals under pressure (Public Technology, 1980).

There is reason to believe that incident/accident databases can be used to improve emergency response and disaster preparedness. For example, knowledge of high accident frequency locations and the flow of hazardous materials provides communities with a better understanding of the probability of an incident and the likely materials involved.

There have also been a broad set of requests for both accident and incident data from the private sector, including legal professionals, industry analysts, private citizens, consultants and university researchers. In most cases, these are handled through distributions of a hard copy of the requested material. Some databases are also accessible through on-line queries via telephone access.

A.5 SUMMARY

This appendix has focused on the reporting and data collection of accidents/incidents involving hazardous material transport. As noted, the regulatory environment has evolved to a point where OHMT should be the repository of information on hazardous materials transport incidents. Data collected by DOT modal administrations focus more generally on vehicular accidents, yet permit the identification of accidents which involve hazardous materials. Other databases serve a purpose of identifying either hazardous material transport accidents or incidents. Because of this connectivity capability, the availability of these "secondary" databases in a supporting role is an invaluable resource.

The HMIS database maintained by OHMT has become the best source of data on the causes, events and consequences surrounding hazardous materials incidents. However, several reporting and data collection deficiencies exist, which make it difficult to conduct unbiased analyses of hazardous materials transport incidents and safety without additional verification. The most useful sources of additional verification appear to be the NRC telephone reports, NTSB investigations database, state and Federal agency accident files, and other related databases.

The NTSB damage estimates and probable causes are likely to be more accurate than those filed by the carrier within 15 days to OHMT. The number of incidents and accidents involving hazardous materials that go unreported to OHMT can be identified, in some respects, by examining accident reports filed to the modal administrations, state agencies and NHTSA, and incident reports filed with NRC, and comparing them to incidents reported in the HMIS file (even after this process, the number of unreported events may still be significant). This is particularly important in the case of the marine mode, where reports on incidents involving hazardous materials transported in bulk are not requested by OHMT.

Although the additional sources of information are extremely important, in practice it is quite difficult to establish congruence among any of the databases. This is due to several reasons, the most important of which are different definitions of accidents and incidents, criteria for a reportable event, ability to track a hazardous cargo movement, and level of detail concerning specific commodity, contributing factors, consequences, etc. Thus, the secondary data is not an adequate substitute for an improved primary information system.

A number of suggestions have been made to improve the accuracy and completeness of hazardous materials incident reporting. These recommendations focus on the contents of the incident report form, criteria and procedures for incident notification, and internal management of reported information (Abkowitz and List, 1986).

For example, Form F5800.1 can be modified in format so that it is more standardized and does not allow for too much flexibility in response that has led in the past to incomplete reports and subjective judgments of OHMT data entry clerks. This would also simplify the data entry process, and diminish the likelihood of redundant codes allowable for the same data entry field. The amount of information required on Form F5800.1 does not appear to be excessive when contrasted with other incident/accident reporting systems, and could actually be expanded to include a few additional characteristics of the incident, if desired.

OHMT should remove the "voluntary" notion of incident reporting via policy initiative and/or new legislation requiring mandatory reporting of incidents meeting the reporting criteria. In order to enforce more stringent requirements, the penalties for non-compliance must be increased substantially in severity. In response to issues raised by carriers, it would be beneficial to extend the reporting limit beyond 15 days, and perhaps shippers and receivers should also be required to file written reports when incidents involve loading/unloading operations.

Finally, OHMT management should focus internally on improving the completeness of filed reports, identifying and mediating mis-reporting, and identifying and prosecuting non-reported incidents which meet the OHMT reporting criteria. This requires the cooperation of other government agencies in the form of data sharing and perhaps minor modification to their own reporting practices.

None of these recommendations are resource-intensive; in some cases, only one time developmental expenses would be incurred. In light of the inadequacies in the present information system, this is a relatively inexpensive program for establishing a comprehensive basis for monitoring and regulating safety in the hazardous materials transport industry.

A.6 REFERENCES

Abkowitz, Mark and George List, 1986. Hazardous Materials Transportation: Commodity Flow and Incident/Accident Information Systems, Final Report, prepared for Office of Technology Assessment.

City of Indianapolis - Emergency Management Division, 1983. Demonstration Project to Develop A Regional Hazardous Materials Accident Prevention and Emergency Response Program.

General Services Administration, 1984. Code of Federal Regulations - Transportation, 49, Parts 100 to 177, U.S. Government Printing Office.

ICF, Inc., 1985. Economic Analysis of Reportable Quantity Adjustments Under Sections 102 and 103 of the Comprehensive Environmental Response, Compensation and Liability Act.

Materials Transportation Bureau, 1980. Guide for Preparing Hazardous Materials Incident Reports, USDOT-RSPA.

National Conference of State Legislatures, 1984. Hazardous Materials Transportation: A Legislator's Guide.

NHTSA, 1981a. National Accident Sampling System (NASS), Analytical User's Manual.

NHTSA, 1981b. Fatal Accident Reporting Systems (FARS), User's Guide.

Public Technology, Inc., 1980. Transportation of Hazardous Materials.

Scanlon, Raymond D., 1983. A Regional Study on Hazardous Materials Transportation, Howard S. Cullman Fellowship Report.

Transportation Research Board, 1983. Transportation of Hazardous Materials: Toward a National Strategy, Volume 1, Special Report 197.

U.S. Coast Guard, 1984. Coding Instructions for the Automated File of Commercial Vessel Casualties.

U.S. Coast Guard, 1983. Polluting Incidents In and Around U.S. Waters, Calendar Year 1981 and 1982.

U.S. Department of Transportation - RSPA, 1983. A Guide to the Federal Hazardous Materials Transportation Regulatory Program.

U.S. General Accounting Office, 1980. Programs for Ensuring the Safe Transportation of Hazardous Materials Need Improvement.