July 1982
NHTSA Technical Report

DOT HS-806 300

U.S. Department of Transportation

National Highway Traffic Safety Administration

Large-Truck Accident Causation

Research and Development
National Center for Statistics and Analysis

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

HE
5613.5
.L37
T32

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 806 300		

4. Title and Subtitle	5. Report Date
Large Truck Accident Causation	July 1982
	6. Performing Organization Code: NRD-32
7. Author(s): Eicher, J.P.; Robertson, H.D.; and Toth, G.R.	8. Performing Organization Report No.
9. Performing Organization Name and Address: Accident Investigation Division, (NRD-32) National Center for Statistics & Analysis National Highway Traffic Safety Administration 400 - 7th Street, SW Washington, DC 20590	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address: National Highway Traffic Safety Administration 400 - 7th Street, SW Washington, DC 20590	13. Type of Report and Period Covered: Final Report January 1981 - July 1982 14. Sponsoring Agency Code

15. Supplementary Notes

This report was prepared by the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) in cooperation with the Federal Highway Administration (FHWA) for the Senate Committee on Appropriations.

16. Abstract

Accidents involving large trucks (more than 10,000 pounds gross vehicle weight) are a serious safety problem on our Nation's highways. In 1979-1980 large trucks were involved in an annual average of 5.7 percent (385,000) of all police-reported accidents. Yet, they accounted for 11.8 percent (5,360) of all fatal accidents, in which 5,874 persons died.

This report identifies the driver, vehicle, and the highway/environmental factors and the operational practices which contribute to the frequency and severity of accidents involving large trucks. Analyses did not reveal any single solution which, if implemented, would guarantee alteration of the truck accident problem. They did, however, indicate areas in which the greatest probability exists of reducing the number of truck accidents and their consequences.

17. Key Words	18. Distribution Statement
Traffic Accident, Large-Trucks, Highway Safety, Accident Statistics, Accident Data	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
unclassified	unclassified	215	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

This report was made possible through the efforts of a large number of individuals. The cooperation and contributions of the following individuals and agencies are gratefully acknowledged:

Working Group

Gary R. Toth, National Center for Statistics and Analysis (NCSA), NHTSA
Robert M. Clarke, Office of Heavy Duty Vehicle Research, NHTSA
Noble Bowie, Bureau of Motor Carrier Safety, FHWA
Joseph Cameron, Office of Plans and Programs, NHTSA
Michael D. Freitas, Office of Research, FHWA
Charles Overbey, Office of Driver and Pedestrian Research, NHTSA
Sue Partyka, NCSA, NHTSA
Dan Najjar, NCSA, NHTSA

Coordinating Committee

H. Douglas Robertson, Chairman, NCSA, NHTSA
John P. Eicher, NCSA, NHTSA
William A. Leasure, Office of Heavy Duty Vehicle Research, NHTSA
James O'Steen, Bureau of Motor Carrier Safety, FHWA
David Solomon, Office of Research, FHWA
Joseph Delahanty, Office of Plans and Programs, NHTSA
Robert M. Nicholson, Office of Driver and Pedestrian Research, NHTSA
David R. McElhaney, Office of Highway Planning, FHWA
Jerry Tannahill, Office of Driver and Pedestrian Programs, NHTSA
Norman C. Mueller, Office of Highway Planning, FHWA
John M. Machey, Office of Vehicle Safety Standards, NHTSA
John D. Cutrell, Office of Programs and Policy Planning, FHWA
Joseph H. Engel, NCSA, NHTSA
Benjamin V. Chatfield, Office of Highway Safety, FHWA
Paul Levy, Office of Programs and Demonstration Evaluation, NHTSA
Harold Thursby, Office of Vehicles in Use, NHTSA
John Law, Office of Heavy Duty Vehicle Research, NHTSA

TABLE OF CONTENTS

25919

APR 2 1 2000

HE
5613.5
.L37
T32

FIGURE		Page

This report was prepared by the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) in cooperation with the Federal Highway Administration (FHWA) for the Senate Committee on Appropriations.

INTRODUCTION

Accidents involving large trucks (more than 10,000 pounds gross vehicle weight) are a serious safety problem on our Nation's highways. In 1979-1980*, large trucks were involved in 5.7 percent (385,000) of all police-reported accidents. Yet, they accounted for 11.8 percent (5,360) of all fatal accidents, in which 5,874 persons died.

This report identifies the driver, vehicle, and highway/environmental factors and the operational practices which contribute to the frequency and severity of accidents involving large trucks. Analyses did not reveal any single solution which, if implemented, would guarantee alteration of the truck accident problem. They did, however, indicate areas in which the greatest probability exists of reducing the number of truck accidents and their consequences. Full implementation of the recommendations offered in Section V would improve large-truck safety significantly.

As expected, the information and data which were assembled and analyzed do not permit conclusive answers to many questions regarding large-truck accident causation. Ongoing and planned efforts by NHTSA and FHWA to acquire and analyze improved accident and travel data will permit better understanding. Moreover, it is unrealistic to depend solely on accident data for answers to several questions related to the improvement of large-truck safety due to some inherent limitations in the evidence available from post-crash investigations. For this reason, NHTSA and FHWA have successfully used and will continue to use engineering analysis and vehicle testing to identify

*Throughout this report, 1979-1980 indicates that the data presented are an annual average.

safety problems and to develop countermeasures in those areas in which necessary accident data are either unavailable or too costly to collect. This report includes information on large-truck safety problems identified through accident data analysis as well as through engineering analysis and experimentation.

THE U.S. TRUCKING INDUSTRY

About 20 percent of the estimated 27 million trucks in use in the United States in 1977, were large trucks. These represented 4.0 percent of all registered vehicles and accounted for 6.7 percent of all vehicle miles travelled. Nearly one-fifth of the large trucks were combination trucks and more than four-fifths were single-unit trucks, but the typical combination truck travelled more than four times the annual mileage of the typical single-unit truck.

For the most part, the trucking industry consists of two major groups, for-hire and private carriers. For-hire carriers transport freight for others, and private carriers transport their own goods and supplies. Economic deregulation now permits private carriers to act as for-hire carriers under certain conditions.

In 1977 interstate for-hire carriers operated 9 percent of all large trucks in use and accounted for 27 percent of total interstate large-truck mileage. Although private carriers operated more trucks over more total miles, the average mileage of for-hire trucks operating interstate was greater than four times that of private-carrier trucks.

"Owner-operators" or "independent truckers" own about 100,000 vehicles, of which 60 percent are leased to for-hire carriers and 40 percent operate as independents. Significant differences exist among various segments of the trucking industry in scheduling procedures, maintenance procedures, and mileage driven.

TRUCK ACCIDENT EXPERIENCE

Large trucks were involved in 5.7 percent of all police-reported accidents in 1979-1980, but in 11.8 percent of all fatal accidents. These percentages were less than those for passenger cars and light trucks and vans, but the relative proportion of fatal accidents to all accidents was much greater for large trucks than that for cars or light trucks and vans.

Overall, large trucks were involved in fewer accidents per mile of travel than were passenger cars, but the proportion of accident-involved trucks to the number of registered trucks was slightly higher than that for cars. The opposite was true with regard to fatal accidents: large trucks experienced almost twice the fatal accident rate per mile travelled than did passenger cars. Stated another way, although accidents involving large trucks were less likely to occur than accidents involving passenger cars, the consequences of large-truck accidents were much more severe.

About three-fourths of all large-truck accidents, both fatal and nonfatal, involved two or more vehicles. When a large truck collided with another vehicle, it was more than three times as likely to be with a passenger car as not. In such collisions, occupants of the other vehicles were more likely to be killed or injured than were occupants of the truck.

The number of fatal accidents has increased each year from 1976 to 1980 but the rate of increase has been slowing. In 1980 there was almost no increase above the 1979 rate and a slight decrease in that rate was experienced in 1981. The number of fatal accidents involving large trucks also increased each year from 1976 to 1979, but decreased 11 percent in 1980. A further 3 percent decrease was observed for 1981. The recent decline in fatal accidents may be attributable in part to a reduction in vehicle miles of travel as a result of economic slowdown.

The future accident experience of large trucks will be influenced by vehicle miles of travel (VMT) and the changing vehicle mix. If VMT for large trucks in the next decade continues to increase and the rate of fatal large-truck accidents per VMT remains constant, then the proportion of fatal accidents that involve large trucks can be expected to rise from about 12 percent in 1978 to almost 14 percent in 1990. Recent trends indicate that large-truck VMT is increasing at a higher rate than the remainder of the vehicle population. The number of vehicles using the Nation's highways is expected to increase during the 1980s while the amount of new highway mileage is expected to increase only slightly. The increased competition for highway space by more vehicles can be expected to result in more frequent collisions.

By the mid-1980s smaller and lighter cars are expected to become the majority of the car population. Moreover, the type of accidents in which most persons were killed has changed from single-vehicle crashes in the 1950s to multiple-vehicle crashes. The increasing likelihood of collisions between smaller vehicles and heavier vehicles will contribute to an increased risk to occupants of smaller cars.

CONTRIBUTING FACTORS TO TRUCK ACCIDENTS

Driver-Related Factors

- Age: Young drivers have higher accident rates than any other driver group. This is particularly true for drivers of large trucks. Accident rates per VMT are highest for young drivers (under 30), and lowest for middle-aged drivers (30-49). Truck drivers under age 25 are twice as likely to be involved in an accident as are passenger car drivers under 25. Truck drivers more than 49 years old had accident rates slightly higher than did the middle-aged group but much lower than did young drivers. A survey of truck drivers has indicated that those under 25 drove more often at higher speeds, drove more often beyond the ten consecutive hours permitted by the Bureau of Motor Carrier Safety (BMCS), and had more moving violations and accidents than did older drivers. Also, drivers under 25 were more frequently employed hauling ICC-exempt commodities than drivers for common or contract carriers and were consequently less subject to enforcement of safety regulations.

- Training: A majority of the drivers surveyed had no formal training. Data for 1979 showed that only 15 percent of accident-involved truck drivers had any formal commercial-driver education.

- Fatigue: Although a direct relationship between accidents and hours-of-service is lacking, studies have found significant increases in driving errors and decreases in driver alertness due to fatigue well within the ten-hour limit allowed by BMCS regulations. Among other findings: cumulative fatigue effects appeared after four consecutive days on duty; adverse effects of prolonged driving were more pronounced among drivers over age 44 than among younger drivers; more single-vehicle accidents and accidents involving dozing at the wheel occurred during early morning hours; and drivers on irregular schedules experienced more fatigue effects than did regular-route drivers.

- Alcohol Involvement: The role of alcohol in vehicle accidents has been studied extensively and is well established among passenger car drivers, but the role of alcohol in accidents involving large trucks has not yet been so well defined. This is attributable to a higher emphasis on passenger car drivers in previous research as well as difficulties in acquiring alcohol information on drivers of large trucks.

- Drug Use: Data associating drug use to highway accident occurrence is also lacking. Accident studies have attempted to identify the problem but none has focused on drivers of large trucks. A survey of truck drivers, however, reported that drivers under 25 used marijuana and amphetamines more often than did other age groups.

- <u>Driver Qualification</u>: Thirty-one States test applicants for truck driver licenses in the type of vehicle to be driven, and both States and motor carriers are required to maintain driver-violation histories. However, procedures to monitor driver-violation histories and to conduct background investigations on prospective employees rely on the drivers' self-reported information. Many practices exist by which drivers avoid placement of violations on their records. Maintaining multiple licenses and records within different States is one frequently used practice.

- <u>Driver-Safety Motivation Programs</u>: Motor carriers for years have successfully used awards programs as incentives for accident-free driving. Evidence exists that fuel-efficient driving may also reduce the frequency of truck accidents significantly. More recently carriers have been providing incentives for fuel-efficient driving.

<u>Vehicle-Related Factors</u>

- <u>Vehicle Design and Weight</u>: Differences exist in the accident and severity rates among large trucks of different types. Particular attention has been given to the safety records of multiple-trailer combinations. Nine studies have compared the records of single-trailer and double-trailer combination trucks. Four of these have indicated that double-trailer combinations are less frequently involved in accidents but noted that this could be the result of stricter operational conditions such as the employment of more experienced drivers or the safer highway environments in which they were observed. Three studies, two in the early 1970s and one in 1979, have found no difference between accident involvements for single- and double-trailer combination trucks, and two other studies have shown that double-trailer trucks tend to experience both higher accident rates and higher injury and fatality rates.

Although one study has indicated that fatality rates for car occupants in car-truck collisions increase as the weight of the truck increases, the effects of truck weight on accident causation are not known. A recent FHWA study showed an inverse relationship between accident occurrence and truck weight and indicated that articulated trucks, especially double-trailers, experience a significantly higher accident rate when operated empty. Understanding of the effect of truck weight on accident occurrence and severity is hampered because many data bases reflect only registered truck weight rather than actual loaded weight at the time of the accident.

- <u>Crashworthiness</u>: In 1981, 1,131 occupants of large trucks were killed. Seventy-two percent were occupants of combination trucks. While many of the fatal accidents involving combination trucks were collisions with fixed objects, death was most often attributed to rollovers.

  The combination-truck occupant most often killed was the driver (82 percent). Fatally injured truck occupants, similar to fatally injured passenger car occupants, were almost never using a safety belt (97 percent). Thirty-five percent of the combination-truck occupants killed were ejected from the truck. Studies have indicated that occupant fatalities occur more frequently in cab-over-engine tractors than in the conventional cab-behind-engine tractors.

  The largest group of large-truck accidents that resulted in fatalities were collisions of large trucks with other motor vehicles, and most of these fatalities in other motor vehicles were passenger car occupants (71 percent). Most of these two-vehicle collisions were head-on impacts. More large trucks struck passenger cars than were struck by them in frontal collisions, but the reverse was true in front-to-rear crashes.

- <u>Crash Avoidance</u>: The braking system of trucks is the most important vehicle component in the prevention of truck accidents. Two types of truck accidents that involve braking capabilities involve the inability to stop in time and loss of directional control. A reduction in the frequency of truck accidents may be possible by shortening the stopping distance of trucks with simple brake adjustments and repairs. Braking systems account for the largest group of safety problems found in the BMCS inspections that resulted in trucks being removed from service.

  Truck instability during braking and compensating steering maneuvers often results in rollover or jackknife accidents. About half of all single-vehicle truck accidents involve either rollover or jackknifing. Such accidents are high-risk events for truck occupants. One study has found that 56.2 percent of combination-truck occupant fatalities result from rollover accidents and 55.6 percent of all combination-truck occupant injuries result from jackknife accidents.

Crash avoidance capabilities of large trucks could be improved by:

-- Better braking performance, especially for empty trucks and trailers,

-- Retarders that assist brakes to control downhill speeds,

-- Tire designs that reduce stopping distance and improve directional stability,

-- Proper tire inflation to reduce the potential for blowouts under heavy loads,

-- Systems to control spray from truck tires during wet weather,

-- Improved vehicle conspicuity and lighting systems,

-- Systems to improve rear vision,

-- Standardized driver controls and displays, and

-- Improved defrost and defog systems.

There is some limited evidence which links these crash-avoidance factors to the frequency and severity of accidents. As a general rule vehicles should be compatible with the limitations and abilities of drivers.

Highway/Environmental-Related Factors

o Interchanges and Intersections: A six-State accident sample has indicated that on controlled access highways 16 percent of large-truck accidents occur at interchanges (10 percent for rural and 21 percent for urban freeways). The study also found that large trucks experience fewer accidents at on-ramps than at off-ramps. More "collision" accidents occurred at on-ramps and more "non-collision" accidents occurred at off-ramps. Truck accidents at intersections accounted for 65 and 23 percent of total truck accidents on urban and rural nonfreeway roads respectively.

o Grades: Almost one-third of all fatalities associated with combination-truck accidents occur in accidents on grades. Poor ability to maintain speed on upgrades poses a hazard of trucks being rear-ended by following vehicles. Trucks are often provided with climbing lanes primarily to facilitate traffic flow, but these lanes have safety benefits as well. Single-vehicle truck accidents are more likely to occur on downgrades than on upgrades. On downgrades, the risk of "runaway" accidents and of rear-ending slower-moving vehicles can be reduced by escape ramps and advisory signing. Downgrade accidents are more prevalent on rural nonfreeways than on other types of roadway.

- Curves: The percentage of truck accidents that occur on curves ranges from 7 percent on urban nonfreeways to 34 percent on rural nonfreeways. According to 1979 data, 44 percent of the single-vehicle accidents that resulted in the death of a combination-truck driver occurred on curves.

- Stopping Sight Distance: The distance travelled from the time a driver sees a hazard to the time he can bring his vehicle to a stop is critical on crest vertical curves designed for the stopping requirements of cars. At sharp hill crests, even the higher elevation of drivers of large trucks and consequent earlier warning of a hazard ahead may not in fact compensate for the longer stopping distances required by large trucks.

- Roadside Hazards: Development of guardrails and barriers to contain heavier vehicles did not begin until the early 1970s. Recent accident data indicate an increase in truck collisions with guardrails and barriers. These restraining devices tend to redirect striking automobiles but, because of their weight and higher center of gravity, large trucks often penetrate the barrier or overturn upon impact.

- Speed Differentials: One effect of the National 55 mph speed limit has been to reduce the speed differential between cars and trucks. After the speed limit was implemented significant decreases were observed in the frequencies of large-truck rear-end collisions, large-truck accident rates, and accident severity on interstate and four-lane highways.

- Lighting and Weather: Truck accidents tend to be more severe during the late night and early morning hours and during other periods when poor lighting conditions exist. Almost 22 percent of accidents involving large trucks occur during adverse weather conditions This is slightly higher than the 20 percent of passenger car accidents occurring under similar conditions.

KEY RECOMMENDATIONS

The major recommendations of the report are summarized below. Additional recommendations and important research and development needs are presented in Section V (pp. V-7 to V-13).

Motor Carriers Should:

- Ensure that drivers comply with motor carrier safety regulations.
- Conduct pre-trip and post-trip truck inspections.
- Implement effective truck maintenance programs emphasizing braking systems.
- Improve driver qualifications through pre-employment background screening and increased training, with special attention to the training, supervision, and monitoring of young drivers, and increase training to familiarize drivers with large-truck handling and braking capabilities.
- Ensure that safety belts are installed in all trucks and require their use by drivers.

Large-Truck Manufacturers Should:

- Improve the braking performance of large trucks and trailers, especially when travelling empty, and implement improvements to reduce in-service brake degradation.
- Develop and install more comfortable and convenient safety belt systems for truck occupants.

Federal Government Should:

- Continue Federal inspection of large trucks and their drivers and encourage more widespread truck inspection by States. Publicize among motor carriers the economic and safety benefits of improved vehicle maintenance.

- In cooperation with the truck safety community, coordinate the research and development program which complements truck accident and travel data acquisition and analysis activities. (Research and development needs are listed on pp. V-12 and V-13.)

- Encourage States to evaluate and improve large-truck driver license testing, issuance and control practices, and foster use of the National Driver Register and the Driver License Compact.

- Define in cooperation with the truck safety community the large-truck exposure (travel characteristics) and accident data that are most neede and develop and implement a coordinated plan to fill these needs.

State Governments Should:

- Increase on-road large-truck inspections and broaden authorization for removing vehicles from service.

- Implement and evaluate improved truck-driver license testing and issua procedures and increase compliance with provisions of the Driver Licer Compact and participation in the National Driver Register.

- Continue to join with Federal agencies in attempts to understand large-truck accident phenomena and to determine the effectiveness of alternative countermeasures.

- Increase enforcement efforts of traffic laws relating to large trucks.

State and Federal Government Should:

- Promote use of safety belts by all motor vehicle occupants, specifically including occupants of large trucks.

- Identify and correct the hazards associated with locations that have a high incidence of truck accidents, such as freeway on- and off-ramps, surface street intersections, grades, and curved sections of highway.

- Promote safety countermeasures and safety management techniques.

- Adopt uniform classification and recording of large-truck travel and accident information.

Insurance Companies Should:

- Expand areas of cooperation with NHTSA and FHWA on research efforts by providing available data on large-truck accidents.

Truck Drivers Should:

- Wear safety belts.

- Increase familiarity with large-truck maintenance problems and regularly check their trucks, especially the trucks' brake systems and tires. Insure that front-axle brakes are operative and do not defeat their function.

- Comply with motor carrier safety regulations.

- Not drive under the influence of alcohol and other drugs.

Important Research and Development Needs:

- Continue collection and analysis of large-truck accident and exposure (travel characteristics) data to expand knowledge of accident and injury causation.

- Develop and evaluate large-truck brake system modifications to reduce stopping distances and minimize loss of control.

- Develop and evaluate alternative methods of improving the handling and stability of large trucks.

- Evaluate truck-driver training programs and license testing procedures.

- Evaluate roadway geometric design and traffic control device standards and practices as they apply to the size, weight, and configuration of large trucks.

- Develop and evaluate improved safety belt systems for large trucks.

SECTION I

INTRODUCTION

On behalf of the Secretary of the Department of Transportation (DOT), the National Highway Traffic Safety Administration (NHTSA) has prepared this report on the causes of truck accidents and of injuries that result from them, and general recommendations for effective programs of research, accident data collection, and countermeasure development. NHTSA wishes to acknowledge the support and cooperation of the Federal Highway Administration (FHWA) in preparing this report.

In 1979-1980*, large trucks were involved in 5.7 percent of all traffic accidents and 11.8 percent of all fatal accidents reported to police. It is estimated that during these years, 44 accidents involving large trucks occurred every hour each day of the year and one out of every nine persons killed on the Nation's roadways was the victim of a large-truck accident. Data for 1981 show that 5,779 persons died in accidents involving large trucks (FARS data, NASS data, 1979-1981).

Recognizing this safety problem, the Senate Appropriations Committee directed DOT, in cooperation with other members of the highway safety community, to undertake research and analyses necessary to identify the causes of large-truck accidents and to provide a basis for development of countermeasures.

In report #96-932, which accompanied appropriations for the Department of Transportation and related agencies for the fiscal year ending September 30, 1981, the Senate Appropriations Committee directed DOT:

> ". . . to undertake a comprehensive data collection and analysis of large (greater than 10,000 pounds GVW), medium (10,000 to 26,000 pounds GVW), and heavy (greater than 26,000 pounds GVW) truck accidents. This undertaking

---

*Throughout this report, 1979-1980 indicates that the data presented are an annual average.

should be done in cooperation with other Federal agencies, State transportation or highway departments, truck manufacturers, operators and carriers, labor organizations, associations, police officials, accident investigators and researchers, insurance companies, and other interested and affected parties. Such report shall identify truck accident causative factors and include recommendations so that effective countermeasures to prevent accidents and injuries, both to their occupants and those of other vehicles, can be defined."

OBJECTIVES

The objectives of this report are to identify factors that contribute to the occurrence and severity of truck-related accidents and of the injuries sustained by all persons involved in such accidents, and to recommend the implementation or further development of effective countermeasures.

SCOPE

This report analyzes the human, vehicle, and highway/environmental characteristics of accidents involving large trucks and how these accidents and injuries might be prevented. It is concerned with accidents involving large trucks, defined by the Appropriations Committee as those with a gross vehicle weight (GVW) exceeding 10,000 pounds. The time available did not permit data collection initiatives. Therefore, available truck accident and safety research information, supplemented by the assembly and analysis of existing accident and exposure data files, was employed.

METHODOLOGY

Preparation for this report was two-phased: information gathering and analysis. Information was gathered from four sources: a public docket that solicited outside comments; a Transportation Research Board workshop attended by a broad spectrum of safety specialists and trucking industry-related officials; the literature of available research studies; and existing accident and exposure data of Federal, State and private agencies.

At an early juncture, NHTSA and FHWA formed a joint committee to guide the project and a joint working group to perform project tasks. Groups outside the Federal Government were also involved.

First, a Public Docket (Docket No. 81-06) was established and published in the Federal Register on April 23, 1981 which provided all private and public sectors an opportunity to contribute information at an early stage in the development of the project. Twenty-six organizations and/or individuals submitted analyses, studies, and comments which were used in developing this report. These contributors are listed in Appendix A. This Docket will remain open indefinitely in the hopes of generating additional information as future truck programs develop.

Secondly, the Transportation Research Board (TRB) of the National Academy of Sciences sponsored a two-day workshop on May 4-5, 1981. The proceedings of the workshop are summarized in the TRB publication, Transportation Research Circular (Number 231), September 1981 (Appendix B).

The workshop was attended by 53 representatives of Federal and State Governments, truck manufacturers, the trucking industry, truck insurers, enforcement agencies, labor unions, and safety and research organizations. Workshop groups considered four facets of truck safety: truck accident characteristics, trends, and forecasts; driver characteristics and operations; vehicle characteristics and operations; and highway/environmental factors.

The purpose of the TRB workshop was to assess the state-of-the-art in truck accident data systems. Among the questions workshop participants addressed were the following:

- o What are the important issues that should guide the collection of truck safety data?
- o What data are now available to help study those issues?
- o How good is the quality of, and how complete are existing data?
- o What are potential sources of additional data?

Major accomplishments at the TRB workshop included:

- o Continuation of a spirit of cooperation between Government and the private sector in dealing with the present and future issues in truck safety;
- o Identification of major issues which should be addressed in this report;
- o Identification of data bases and information that had not been previously identified.

The third source of information was a synthesis of prior research cond agencies of the Department of Transportation, various States, and pr organizations (McGee, 1981). This comprehensive review of over 190 re..rences from previous research described large-truck accident characteristics including accident dynamics, vehicle and driver factors, highway conditions, alcohol, driver fatigue, vehicle defects, and other issues of concern in truck safety. Additional references were identified by NHTSA staff.

The last source of information was the accident data files maintained by NHTSA and FHWA. Of particular importance were two NHTSA files--the National Accident Sampling System (NASS) and the Fatal Accident Reporting System (FARS)--and a FHWA file maintained by the Bureau of Motor Carrier Safety (BMCS). Appendix C contains a discussion of the characteristics, strengths, and weaknesses of the major data bases used in this report.

The information and data gathered from these sources were subjected to analysis as were the methods and findings of previous research and data bases. The results of these efforts were then synthesized and interpreted.

REPORT TERMINOLOGY

Throughout the literature, the terminology used to describe trucks varies. Terms like heavy truck, medium truck, straight truck, single-unit truck, combination truck, tractor-trailer, singles, tractor-semitrailer, tractor-semi-full, tractor-semi-full-full, doubles, triples, and bobtails sometimes are interchanged, incorrectly interpreted, or confused. To provide a standard nomenclature for this report, large trucks are subdivided into two weight groups--10,000 to 26,000 pounds and more than 26,000 pounds. The term commonly applied to the former weight group is medium-weight truck and to the latter, heavy truck. Unless stated otherwise, the descriptive words "single-unit" and "combination" will be used to represent the characteristics of medium and heavy trucks, respectively. "Single-unit" trucks are considered non-articulated vehicles; "combination" trucks are articulated.

It should be recognized that, contrary to the selected nomenclature for truck classification, a small percentage of non-articulated vehicles are in the heavy-weight truck group. About 23 percent of all single-unit trucks in the 1979 NASS and FARS, 1977 Truck Inventory and Use Survey (TIU), and FHWA Cost Allocation Study (HCAS) exceeded the registered gross vehicle weight of 26,000 pounds. In particular, the four data files respectively showed that 13.4

percent, 7.4 percent, 30.2 percent, and 49 percent of all trucks greater than 26,000 pounds were classified as single-unit trucks. Regardless of registered weight, all single-unit trucks have been aggregated by configuration rather than weight, unless indicated otherwise.

REPORT STRUCTURE

The report is organized into four major sections. Section II describes the organization and operating practices of the U.S. trucking industry. Section III describes the large-truck accident experience. Section IV outlines approaches to accident causation as a preface to discussions of driver, vehicle, and highway/environmental factors that contribute to accidents involving large trucks and injuries resulting from them. Section V presents findings, conclusions, and recommendations.

SECTION II

THE U.S. TRUCKING INDUSTRY

This section describes the U.S. motor carrier industry, its operating practices that are relevant to this study and the regulatory structures under which it operates. It also discusses the population of large trucks in use by that industry and the mileages travelled by those vehicles as reflected in available data. Structure and practices of the industry may themselves influence safety in trucking and the viability and potential effectiveness of countermeasures to reduce the risk and severity of truck accidents. Such considerations are also important to any attempt to build a reliable base of travel information that would permit calculation of accident rates for the different types of trucks and truck trips.

STRUCTURE OF THE MOTOR CARRIER INDUSTRY

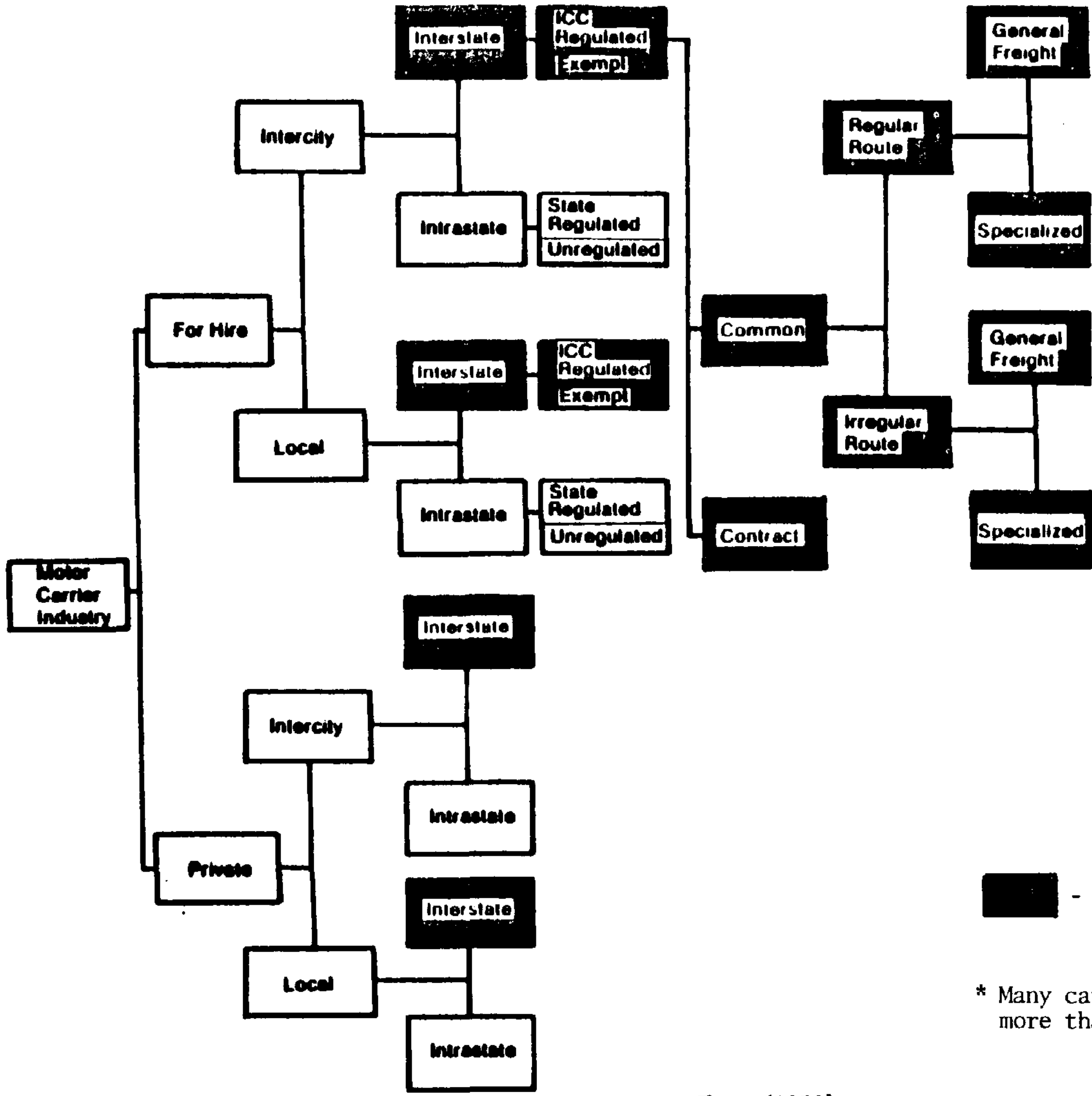
The trucking industry consists of two major groups of carriers, for-hire and private. The variety of operations in which they engage are shown in Figure II-1 (Chow, 1978).

For-hire carriers transport freight that belongs to others. They can also be classified by the jurisdictions they serve: interstate, intrastate and local, the latter two operations regulated by state and local authorities. Most intercity for-hire trucking and some local operations also involve interstate commerce and as such are subject to regulation by the Interstate Commerce Commission (ICC). The ICC lists about 22,000 carriers that have for-hire authority. These account for about 10 percent of all interstate carriers.

Private carriers are those which transport their own cargos as part of another, nontrucking enterprise. Recent legislation deregulating the trucking industry enables private carriers to act as for-hire carriers under certain conditions. This probably represents a small portion of overall private carrier operations. Private carriers transport a significant portion of the country's intercity highway freight. In 1977 they operated almost 83 percent of all the large trucks in use and accounted for 61 percent of the vehicle

FIGURE II-1

STRUCTURE OF THE MOTOR CARRIER INDUSTRY*



■ - Subject to Federal Motor Carrier Safety Regulations

* Many carriers may fall under more than one category

Source: Chow (1978)

miles travelled (Table II-1). The Bureau of Motor Carrier Safety (BMCS) estimates that 57 percent of all interstate motor carriers are private carriers. They are exempt from both ICC and State economic regulation, though they are subject to all applicable safety and taxation regulations and statutes.

In most cases, both for-hire and private carriers engaged in interstate transport must comply with Federal Motor Carrier Safety Regulations (FMCSR) promulgated and enforced by BMCS. The regulations include requirements that apply to drivers' hours of service, accident reporting and recording, driver qualifications, and vehicle inspection and maintenance. BMCS has estimated that more than 176,000 carriers are subject to its regulations. Although other carriers are not subject to such regulations, to limit property losses some have implemented safety management programs which incorporate similar requirements. Two major field activities utilized by BMCS to enforce its regulations are (1) unannounced, periodic, roadside inspections of vehicles and drivers to determine vehicle conditions and loading, and driver documentation, and (2) the Safety Management Audit, the Bureau's primary tool for monitoring compliance with the FMCSR and for determining whether a carrier has implemented an effective safety management program.

Because the BMCS-regulated sector of the industry must comply with safety guidelines and the non-regulated sector may operate under less restrictive controls of driver qualification, driving time, and vehicle maintenance, differences can be expected between their accident rates and general safety records. However, present data do not permit differentiating between the two sectors, and comparisons made between the two must be evaluated with this caveat in mind.

Vehicles operated by private carriers represent the majority of all trucks operating in intercity service. On average they differ from for-hire operations in several relevant ways. The privately owned intercity truck usually has a shorter average length of haul than the for-hire truck and is driven fewer miles each year.

TABLE II-1

TRUCKS AND MILEAGE BY OPERATOR CLASSIFICATION
FOR ALL LARGE TRUCKS IN USE IN 1977

Operator Classification	Trucks (thousands)		Annual Mileage (millions)		Average Annual Miles Per Truck
Not for Hire					
Private Owner, Individual, or Company	4,435.9	(82.6%)	58,750	(61.3%)	13,244
For-Hire Interstate					
Exempt Carrier	73.4	(1.4%)	4,080	(4.3%)	55,586
Common Carrier	276.2	(5.2%)	14,890	(15.6%)	53,910
Contract Carrier	118.6	(2.2%)	6,825	(7.1%)	57,546
For-Hire Intrastate					
Local Cartage	336.5	(6.3%)	7,774	(8.1%)	23,103
For-Hire Daily Rental	103.7	(1.9%)	3,303	(3.4%)	31,851
Not Reported	26.2	(0.4%)	183	(0.2%)	6,985
Totals	5,370.5	100.0%	95,805	100.0%	17,839

Source: FHWA Cost Allocation Study Data (1982)

Types of For-Hire Carriers

For-hire carriers are classified by type of operation: common carriers, contract carriers, and ICC-exempt carriers. Seven percent of all large trucks in use and 23 percent of all travel was by interstate for-hire common and contract carriers. These vehicles had an average annual mileage per truck which was three times the average for all large trucks combined (Table II-1). In interstate operations, for-hire carriers--including ICC-exempt carriers--operated only 9 percent of all large trucks but accounted for 27 percent of large-truck mileage--more than four times the mileage per truck accumulated by the private carrier.

Common carriers offer services to any shipper under authority granted by the ICC. They transport goods between designated points at published rates approved by the ICC for various classes of freight.

Known as a certificate of public convenience and necessity, the authority granted by the ICC to a trucker specifies the types of commodities a trucker may carry and the service routes he may use, whether nonscheduled, irregular route service between areas or regular scheduled service over designated roads. Services not specified in the operating certificate are generally prohibited.

Contract carriers are restricted to serving a shipper or limited number of shippers under specific contracts and may not offer services to the public at large. Their rates differ from those of common carriers, and permits must be obtained from the ICC specifying areas to be served and commodities to be carried.

Certain types of commodities hauled in interstate transport for-hire and transport in certain commercial zones are exempt from ICC regulation but such operations are still subject to part of the FMCSR.

The existence or nonexistence of a causal relationship between the ICC's economic regulation of motor carriers and highway safety has been controversial in recent years. Some have argued that deregulation of the motor carrier industry will result in an increase in motor carrier accident rates. Others have taken an opposite position. A recently completed study (Raven, 1981), consisted of a critical review of data and a survey of some 1,300 truck drivers. It found no relationship between regulatory status and accident rates. However, a review of accident files by Waller and Li (1979) concluded that trucks of ICC-regulated carriers pose less of a safety problem than trucks of exempt-commodity carriers in that the latter are more often judged to be in violation of safety regulations and more likely to have vehicle defects.

Independent Truckers and Lease Operators

An independent trucker is one who does not hold a certificate or permit from the ICC. He may own one truck which he drives himself (an owner-operator), or he may own several trucks and employ drivers. He may be a lease operator or operate independently.

In either case he may haul ICC-exempt commodities or may lease his trucks, with drivers, to regulated carriers. Available evidence indicates there are about 100,000 vehicles owned by independent owner-operators. Of these, about 60 percent are leased to regulated carriers and 40 percent are exempt haulers or independent truckers. It has been estimated these account for 25 to 40 percent of intercity truck operations. Law prohibits private carriers from engaging owner-operators under long-term or trip-lease arrangements.

TRUCKS IN USE AND MILEAGE TRAVELLED

An estimated 27 million trucks were in use in the U.S. in 1977. Of these, 0.9 million (3.4 percent) were combination trucks and 4.4 million (16.5 percent) were single-unit trucks. The remaining 21.7 million were light trucks and vans. The 5.3 million large trucks accounted for 4.0 percent of all registered vehicles in 1977 and 6.7 percent of vehicle miles travelled [FHWA Cost Allocation Study (HCAS) data, 1982].

Figure II-2 shows that, although there were almost five times as many single-unit trucks registered in 1977 as there were combination trucks, they travelled about the same total miles: 49 billion for single-unit trucks, 46 billion for combination trucks.

Travel characteristics of single-unit trucks also differed from those of combination trucks. Combination trucks accumulated almost 4.5 times as many annual miles per truck as did single-unit trucks. The data indicate this was because single-unit trucks were more often used for local and short-haul transport while combination trucks were more often used for long hauls.

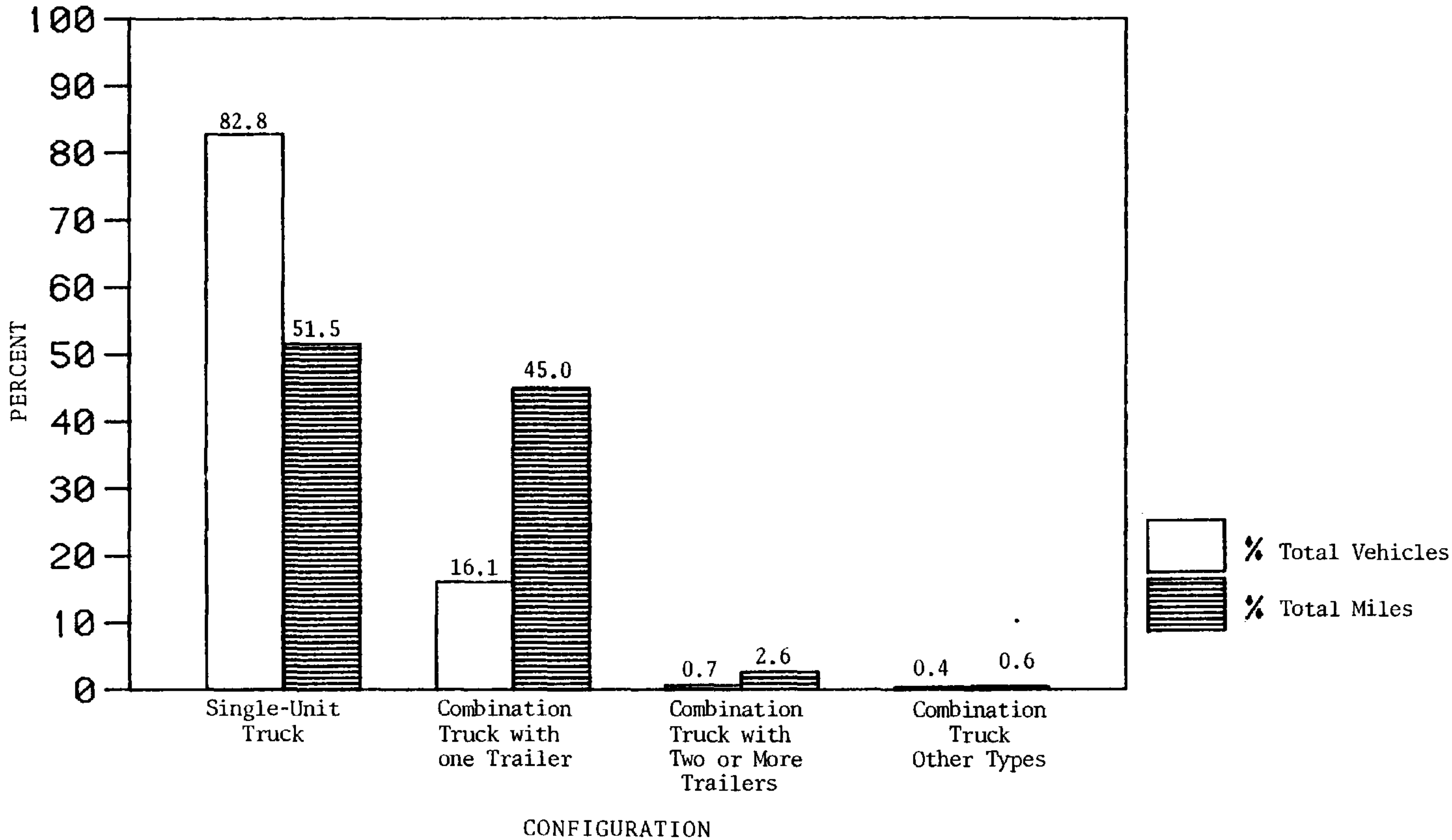
Large fleets (20 vehicles or more) operated 17 percent of all large trucks and accounted for almost 30 percent of total travel while small fleets (5 vehicles or less) operated nearly two-thirds of all trucks but accumulated only about 47 percent of the mileage (Figure II-3). BMCS records indicate only 4,395 interstate motor carriers operate more than 25 vehicles while 161,180 interstate motor carriers operate ten or fewer vehicles. Respectively this is approximately 2.5 and 91.1 percent of the number of carriers regulated by BMCS.

Campbell and Carsten (1981) found that fleets with fewer than 50 trucks are more than twice as likely to experience fatal accidents than fleets with more than 50 trucks. Their study of intercity fleets operating combination trucks

FIGURE II-2

PERCENT DISTRIBUTION OF VEHICLES AND MILES BY

CONFIGURATION FOR LARGE TRUCKS IN USE IN 1977

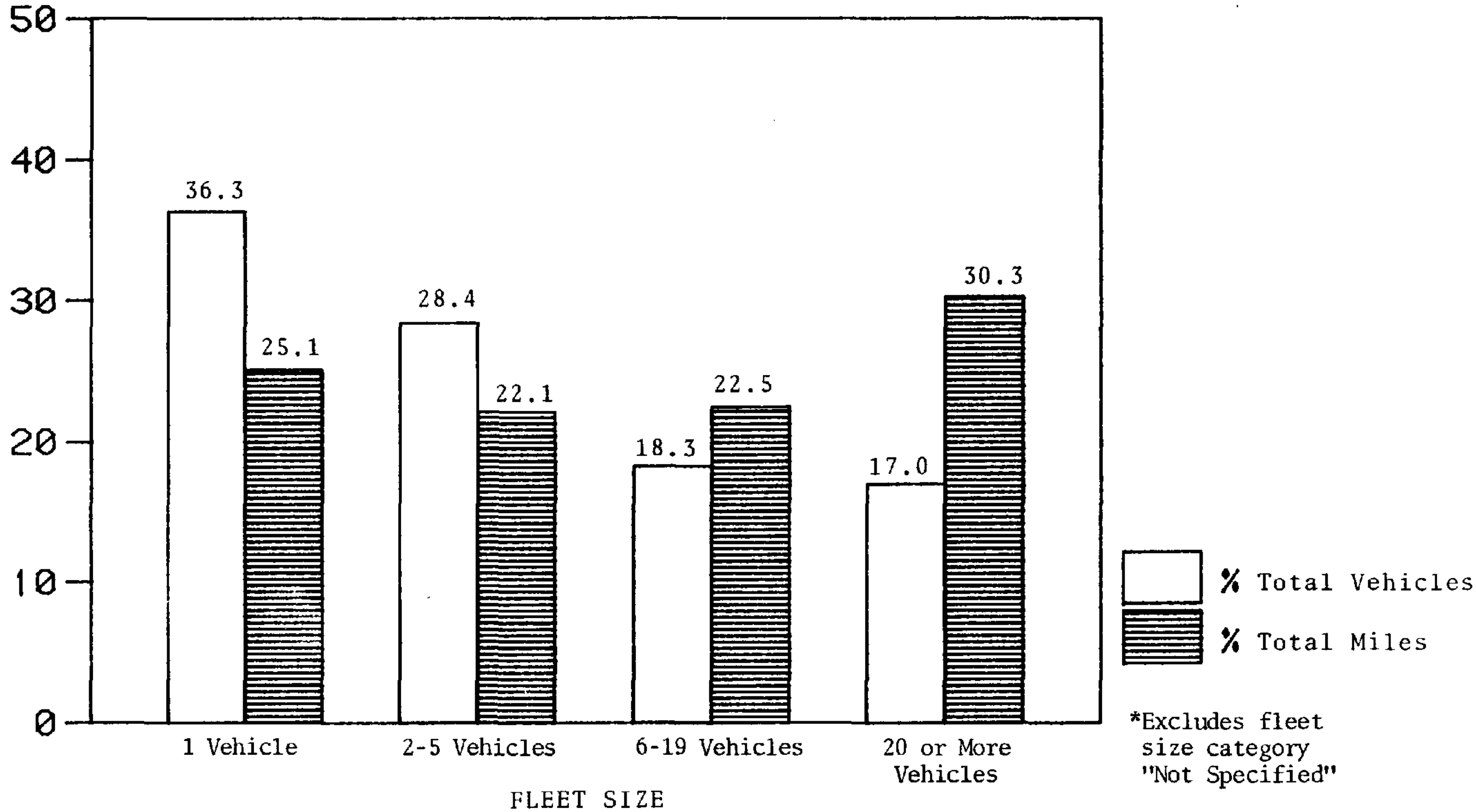


Source: FHWA Cost Allocation Study Data (1982)

FIGURE II-3

PERCENT DISTRIBUTION OF VEHICLES AND MILES

BY FLEET SIZE* FOR LARGE TRUCKS IN USE IN 1977



Source: FHWA Cost Allocation Study Data (1982)

found that fleets with fewer than 50 trucks had a fatal accident rate of 10.4 per 100 million vehicle miles while fleets with more than 50 trucks had a fatal accident rate of 4.6 per 100 million vehicle miles.

Tables II-2 and II-3 distribute transport uses and accumulated mileages across truck configuration and fleet sizes. Manufacturing, wholesale and for-hire trucking are characterized by generally larger fleets, and construction, retail and, especially, agriculture tend to use smaller fleets. The agriculture, construction, wholesale and retail truckers who are mostly private carriers, more often use single-unit trucks and generate comparatively low mileages. Conversely, manufacturing and, in particular, for-hire groups most frequently use combination trucks with the associated higher annual mileages. In comparison to single-unit trucks, combination trucks:

- Are mostly used in for-hire transportation - Of all combination trucks, 40 percent are used in for-hire transportation and accumulate nearly 48 percent of the VMT for combination trucks. On the other hand, only 4 percent of all single-unit trucks are used for this purpose and account for 6 percent of the VMT for single-unit trucks. (Table II-2)

- Operate in large fleets (20 vehicles or more) - Nearly 35 percent of all combination trucks and 42 percent of their VMT operate in large fleets. The majority (57 percent) of these combination trucks are used in for-hire transportation. Of all single-unit trucks, only 9 percent in large fleets, accumulating 13 percent of the VMT for single-unit trucks. Twelve percent of single-unit trucks in large fleets are used in for-hire transportation. (HCAS data, 1982)

- Have high annual mileage per truck - Average annual mileage per truck for combination trucks accumulate four-and-one-half times the annual average mileage of single-unit trucks. (Table II-2)

TABLE II-2

TRUCKS AND MILEAGE FOR MAJOR USES BY TRUCK TYPE IN 1977

	Trucks (thousands)			Annual Mileage (millions)			Average Annual Miles Per Truck	
Major Uses	Single Unit	Combination	Total	Single Unit	Combination	Total	Single Unit	Combination
Agriculture	1,334.4	77.2	1,411.6	7,992	2,797	10,789	5,989	36,231
Construction	546.3	89.3	635.6	6,473	2,808	9,281	11,849	31,445
Manufacturing	147.9	88.8	236.7	2,074	5,246	7,321	14,023	59,077
Wholesale	439.1	115.6	554.7	8,403	6,229	14,632	19,137	53,884
Retail	396.0	56.4	452.4	5,260	2,488	7,748	13,283	44,113
For Hire	168.0	371.6	539.6	3,173	22,273	25,445	18,887	59,938
Others*	1,416.0	123.9	1,539.9	15,941	4,648	20,589	11,258	37,514
Total	4,447.7	922.8	5,370.5	49,316	46,489	95,805	11,088	50,378

*Other major uses included forestry and lumbering, mining and quarrying, utilities, services, daily rental, personal transportation, other, and not in use

Source: FHWA Cost Allocation Study Data (1982)

TABLE II-3

TRUCKS AND MILEAGE BY FLEET SIZE FOR MAJOR USES IN 1977

	Major Uses							
	Agriculture		Construction		Manufacturing		Wholesale	
Fleet Size	Trucks (thousands)	Average Annual Miles Per Truck	Trucks (thousands)	Average Annual Miles Per Truck	Trucks (thousands)	Average Annual Miles Per Truck	Trucks (thousands)	Average Annual Miles Per Truck
1	576.7 (40.9%)	6,194	169.3 (26.6%)	11,843	59.9 (25.3%)	23,890	89.2 (16.1%)	22,287
2-5	323.6 (22.9%)	8,752	167.0 (26.3%)	12,958	59.4 (25.1%)	27,189	149.2 (26.9%)	25,208
6-19	60.3 (4.3%)	18,972	125.0 (19.7%)	18,088	52.5 (22.2%)	37,105	138.0 (24.9%)	29,536
20 and over	12.6 (0.8%)	40,000	70.9 (11.1%)	22,948	41.9 (17.7%)	47,375	105.5 (19.0%)	30,682
Not Specified	438.4 (31.1%)	6,243	103.4 (16.3%)	11,847	23.0 (9.7%)	14,870	72.8 (13.1%)	21,580
Total	1,411.6 (100%)	7,643	635.6 (100%)	14,602	236.7 (100%)	30,929	554.7 (100%)	26,378

	Major Uses							
	Retail		For Hire		Others*		Total	
Fleet Size	Trucks (thousands)	Average Annual Miles Per Truck	Trucks (thousands)	Average Annual Miles Per Truck	Trucks (thousands)	Average Annual Miles Per Truck	Trucks (thousands)	Average Annual Miles Per Truck
1	106.4 (23.5%)	13,205	97.3 (18.0%)	57,184	364.6 (23.7%)	12,789	1,463.4 (27.2%)	14,078
2-5	143.6 (31.7%)	15,195	69.9 (13.0%)	33,348	229.0 (14.9%)	14,310	1,141.7 (21.3%)	15,891
6-19	80.1 (17.7%)	19,688	129.1 (23.9%)	35,701	152.9 (9.9%)	18,777	737.9 (13.7%)	25,033
20 and over	43.4 (9.6%)	33,110	223.2 (41.4%)	55,605	185.6 (12.0%)	19,429	683.1 (12.8%)	36,299
Not Specified	78.9 (17.5%)	14,537	20.1 (3.7%)	26,368	607.8 (39.5%)	10,155	1,344.4 (25.0%)	10,261
Total	452.4 (100%)	17,126	539.6 (100%)	47,155	1,539.9 (100%)	13,370	5,370.5 (100%)	17,839

*Other major uses included forestry and lumbering, mining and quarrying, utilities, services, daily rental, personal transportation, other, and not in use

Source: FHWA Cost Allocation Study Data (1982)

Approximately 10 percent of all large trucks were used in for-hire transportation. This type of use is characterized by:

- The use of combination trucks - Nearly 69 percent of all large trucks used in for-hire transportation are combination trucks which account for 88 percent of the annual mileage for this major use. In other major transportation uses, only 11 percent of all large trucks used are combination trucks which account for 34 percent of the major use annual mileage. (Table II-2)

- Large fleets - Almost 42 percent of all large trucks used in for-hire transportation operate in large fleets of 20 vehicles or more (Table II-3). Fifty percent of the mileage accumulated by for-hire use vehicles is in large fleets (HCAS data, 1982). Only 10 percent of large trucks used in other types of major uses operate in large fleets (Table II-3) and account for 18 percent of the annual mileage for other major uses (HCAS data, 1982).

- High annual mileage per truck - Average annual mileage per truck for the major use, for-hire, is more than three times the annual average mileage for other major transportation uses. (Table II-2)

OPERATING PRACTICES

Practices differ between company drivers and owner-operators, especially in scheduling and maintenance procedures and in average mileage driven.

Operating conditions for the company driver appear more likely to involve regularly scheduled terminal-to-terminal trips, whereas the owner-operator driver is more likely to be assigned irregular routes with deliveries directly to customers (Wyckoff, 1979).

Many carriers using irregular route patterns also use a mix of company and owner-operator trucks. The tendency appears to be to give preferential treatment to company drivers. They are likely to be dispatched first and to receive preferred loads. Also, assignments for owner-operators to transport cargo to particular destinations do not necessarily provide for return trips with a payload (backhaul). In order to avoid a nonrevenue return trip, the owner-operator often attempts to find his own backhaul (Wyckoff, 1979).

Maintenance practices for the two groups of drivers also seem to differ. Trucking companies appear more likely to provide regular preventive maintenance for their fleets than are owner-operators. A 1978 survey (Motor and Equipment Manufacturer's Association, 1979) illustrated some maintenance practice differences between company fleets and owner-operators. The latter more often relied on truck dealers and general repair shops, while fleets were serviced primarily in-house. The survey also demonstrated that owner-operators tended to drive more miles per year and that their vehicles experienced a longer average working life. Table II-4 shows yearly mileage and service-life differences for fleets and owner-operators.

TABLE II-4

COMPARISON OF VEHICLE LIFE AND USE BETWEEN OWNER-OPERATORS AND FLEETS, 1978 (percent)

	Fleets	Owner-Operators
How many miles per year is one of your heavy duty trucks driven?		
50,000 miles and less	43.3	27.6
50,000-59,999	1.2	1.4
60,000-69,999	7.3	11.9
70,000-79,999	7.9	13.8
80,000-89,999	11.0	14.7
90,000-99,999	6.7	8.5
Over 100,000	22.6	22.1
On the average, what is maximum vehicle life in years?		
5 or less	25.0	30.0
6	7.3	11.8
7	6.7	12.0
8	14.6	9.8
9	6.1	2.0
10	28.1	23.5
Over 10	12.2	10.9
On the average, what is maximum vehicle life in miles?		
200,000 miles or less	22.2	7.4
200-299,999	8.7	8.0
300-399,999	14.1	15.2
400-499,999	12.8	13.6
500-599,999	14.8	22.3
600-699,999	9.4	10.8
Over 700,000	18.1	22.6

Source: Maister (1980)

TRUCK ACCIDENT EXPERIENCE

This section presents data for accidents involving large trucks as compiled by NHTSA's National Accident Sampling System (NASS) from 1979 and 1980 and the Fatal Accident Reporting System (FARS) from 1976 to 1981. The accident experience of large trucks is first presented in the context of all traffic accidents and then described in terms of exposure and accident rates, general characteristics, and projected accident trends. The characteristics and limitations of the data bases used are presented in Appendix C. The sample size for both the 1979 and 1980 NASS data is relatively small (approximately 3,000 cases each year). In order to decrease the sampling error and since the data are inadequate to demonstrate any year-to-year trend information, this report presents the annual average NASS data for the 1979-1980 period. Where appropriate, FARS data are also presented as an annual average for the same period. Any differences noted between the NASS or FARS data presented in this report and the NASS or FARS annual reports are due to the use of later data than those used in the annual reports and some differences in definitions.

LARGE-TRUCK ACCIDENTS IN PERSPECTIVE

Large trucks were involved in 11.1 percent of the fatal accidents in 1981. In these, 5,779 persons died (FARS data, 1981). In 1979-1980 large trucks were involved in an estimated 5.7 percent of all police-reported accidents (NASS data, 1979-1980). Large trucks represented 4.0 percent of all registered vehicles and accounted for 6.7 percent of the total vehicle miles travelled (HCAS data, 1982).

Table III-1 depicts the 1979 and 1980 accident experience for selected types of vehicles. Although not mutually exclusive, the percentages reflect the relative magnitude of involvement by these vehicles in both total accidents and fatal accidents. Of the vehicle types studied, large trucks and motorcycles were involved in a much higher proportion of fatal accidents than of all other police-reported accidents.

TABLE III-1

ACCIDENT EXPERIENCE FOR SELECTED VEHICLE TYPES*

Vehicle Type	1979-1980 Police-Reported Accidents[1] (%)	1979 Fatal Accidents[2] (%)	1980 Fatal Accidents[2] (%)
Accidents involving a:			
-- Passenger Car	85.6	70.6	69.6
-- Large Truck**	5.7	12.6	11.1
-- Light Truck or Van	19.8	23.9	23.9
-- Motorcycle	2.7	10.5	10.8

*No column total is provided because the accidents are not mutually exclusive; e.g., an accident involving a truck and a passenger car is counted in both categories.

**Excludes unknown truck types

Source: [1]NASS (1979-1980) Annual Average
[2]FARS (1979-1980)

EXPOSURE AND ACCIDENT RATES

Truck accident data from seven States were used to estimate national totals (Najjar, 1981). This estimate generally agreed with the 1979 NASS estimate. An estimated 432,000 accidents involved large trucks nationwide during 1978, of which 26 percent resulted in nonfatal injuries and 1.2 percent resulted in fatalities, compared to 400,000 accidents estimated by NASS for 1979, of which 22.3 percent resulted in injuries and 1.4 percent resulted in fatalities. The most recent year commonly available for all State files examined was 1978.

Exposure data (TIU, 1977) was matched with these State data to compute rates of involvement by large trucks in total accidents and fatal accidents (Najjar, 1981). Also, NHTSA and FHWA data were used to compute accident rates of passenger cars for comparison with the rates of other types of vehicles. Table III-2 contains the accident rate for each type of vehicle based on vehicle miles of travel (VMT).

Overall, large trucks were involved in fewer accidents per 100 million miles than were cars, but the proportion of accident-involved trucks to the total number of registered trucks was slightly higher than that for cars. A different pattern was evident when combination trucks (these include both single- and multiple-trailer combinations) were compared to single-unit (non-articulated) trucks: the accident rate per VMT was higher for combination trucks, and the proportion of combination trucks that were involved in accidents was higher.

The rates for fatal accidents and for vehicles involved in fatal accidents were higher for large trucks compared to passenger cars and also higher for combination trucks compared to single-unit trucks (Table III-3).

Combination trucks were more likely to be involved in accidents than passenger cars or single-unit trucks for the same number of vehicle miles travelled, and accidents involving combination trucks were more likely to be fatal. Also, the proportion of combination trucks involved in accidents was about four

TABLE III-2

ACCIDENT AND ACCIDENT-INVOLVED VEHICLE RATES BY TYPE OF VEHICLE

Vehicle Type	1977 Number of Registered Vehicles*	1977 Venicle Miles of Travel* (Million VMT)	VMT per Vehicle	1978 Estimate** of all Accidents	All Accidents per 100 Million VMT	1978 Estimate** of all Accident-Involved Vehicles	Accident-Involved Vehicles per 100 Million VMT	Accident Involved Vehicles per 1000 Registered Vehicles
Total Large Trucks	5,370,500	95,805	17,839	432,000	451	454,000	474	85
Combination Trucks	922,800	46,489	50,378	276,000	594	281,000	604	305
Single-Unit Trucks	4,447,700	49,316	11,088	173,000	351	173,000	351	39
Passenger Cars	120,985,820+	1,120,900+	9,265	5,793,000++	517	9,247,000++	825	76

*Data from FHWA Cost Allocation Study (1982)
**The estimation methodology is explained in the source document. Estimates are rounded to the nearest thousand.
+1979-1980 annual average data from FHWA, Highway Statistics Division
++1979-1980 annual average data from NASS

Source: Najjar (1981)

TABLE III-3

FATAL ACCIDENT AND ACCIDENT-INVOLVED VEHICLE RATES BY TYPE OF VEHICLE

Vehicle Type	1977 Vehicle Miles of Travel (Million VMT)	1978 FARS Fatal Accidents*	Fatal Accidents per 100 Million VMT	1978 FARS Fatal Accident-Involved Vehicle*	Fatal Accident-Involved Vehicles Per 100 Million VMT
Total Large Trucks	95,805	5,066	5.3	5,393	5.6
Combination Trucks	46,489	4,005	8.6	4,239	9.1
Single-Unit Trucks	49,316	1,126	2.3	1,154	2.3
Passenger Cars	1,141,800**	32,028	2.8	40,750	3.6

+Data from FHWA Cost Allocation Study (1982)
*Excludes single-unit trucks with unknown gross vehicle weight.
**1978 data from FHWA, Highway Statistics Division

Source: Najjar (1981)

times the proportion of passenger cars and eight times the proportion of single-unit trucks. One of every three registered combination trucks was involved in an accident in 1978 compared to one of every 26 single-unit trucks and one of every 13 passenger cars.

TRUCK ACCIDENT CHARACTERISTICS

The distribution of types of accidents that involved large trucks in 1979-1980 is shown in Figure III-1. About one-fourth of all truck accidents and one-fourth of all fatal truck accidents were single-vehicle accidents. These were separated into those which also involved a nonmotorist, such as a pedestrian or bicyclist, and those which did not, such as collisions with objects, non-collisions, etc. Nonmotorists were involved in only 5 percent of all the single-vehicle accidents that involved large trucks, but they were involved in 40 percent of those accidents that resulted in a fatality.

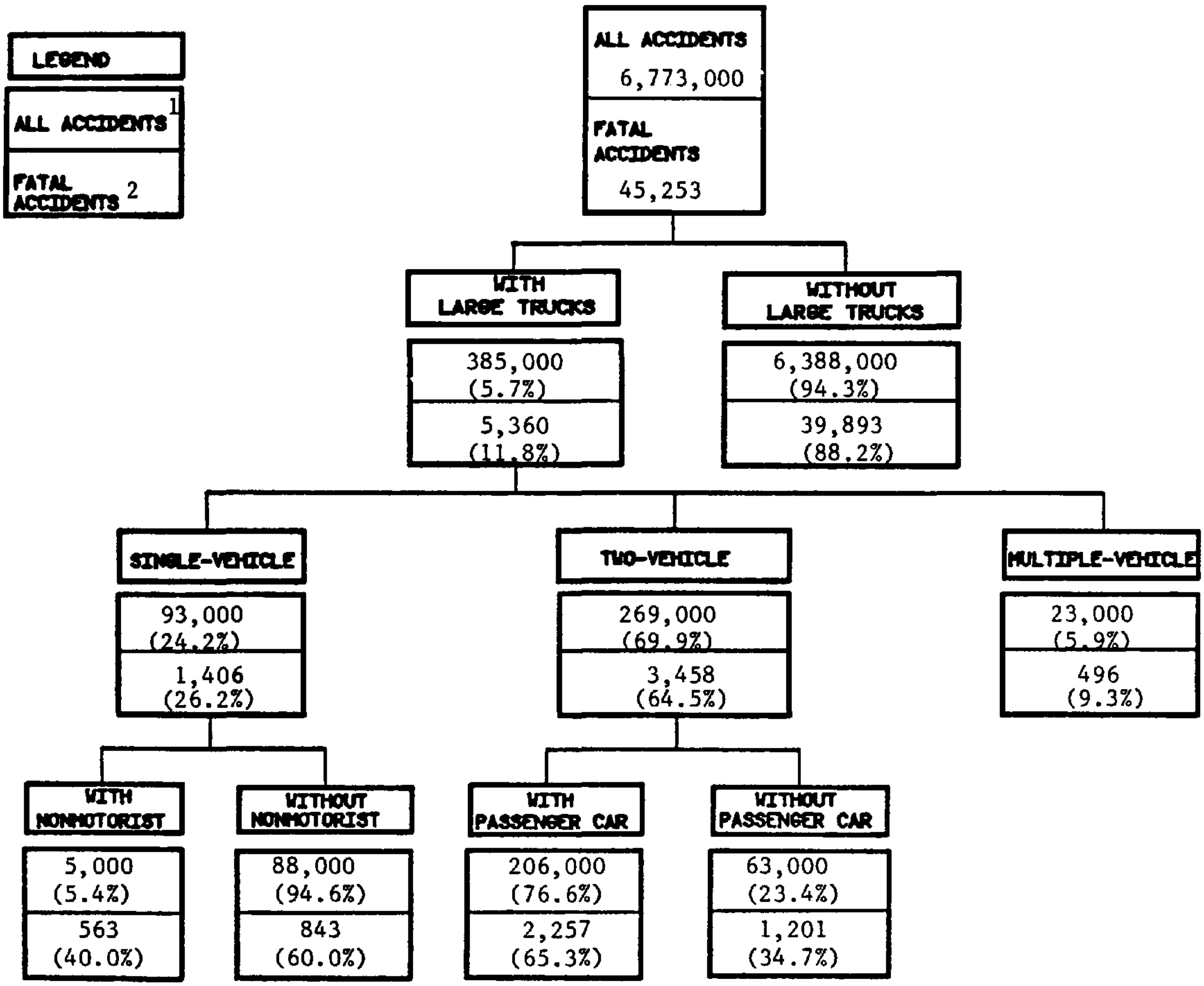
Table III-4 shows the distribution of accident types by first harmful event, defined as the first property-damage or injury producing event that can be determined in the accident. A far greater share of accidents which involved single-unit and combination trucks were of the "non-collision" type (rollover, jackknife, fire, etc.) than was the case for any other kind of vehicle.

Large-truck collisions with another vehicle accounted for 70 percent of all large-truck accidents and 65 percent of all fatal large-truck accidents. When a large truck was involved in a collision with another vehicle, it was more than three times as likely to be with a passenger car than with any other type of vehicle.

Examination of the mix of vehicles in two-vehicle fatal accidents (Table III-5) revealed that about one of every four (22 percent) involved a large truck, but the most common type of two-vehicle fatal accident was car-to-car (36 percent). Of all vehicles involved in fatal two-vehicle collisions, 3 percent were single-unit trucks and 9 percent were combination trucks.

FIGURE III-1

LARGE-TRUCK ACCIDENT EXPERIENCE
1979-1980 ANNUAL AVERAGE



Sources: [1]NASS (1979-1980)
[2]FARS (1979-1980)

TABLE III-4

DISTRIBUTION OF ACCIDENT TYPE BY FIRST HARMFUL EVENT*
(percent of accidents)
1979-1980 ANNUAL AVERAGE

	Passenger Cars	Light Trucks and Vans	Motorcycles	Single-Unit and Combination Trucks
Multiple-Vehicle:				
Collision with another motor vehicle	78.8	81.0	65.5	75.9
Single-Vehicle:				
Collision with other object	17.0	12.9	22.5	12.9
Non-Collision**	1.5	3.4	8.3	10.0
Pedestrian and Nonmotorist	2.5	2.5	3.7	1.2

*First harmful event is the first property-damage or injury producing event that can be determined to have happened in the accident.

**Non-collision includes rollover, overturned, jackknife, fire, explosion, immersion and other non-collision events. Motorcycle overturning accidents are different in nature from rollover of other vehicles because of the inherent instability of two-wheeled vehicles.

Source: NASS (1979-1980)

TABLE III-5

THE NUMBER OF TWO-VEHICLE FATAL ACCIDENTS
BY VEHICLE MIX
1979-1980 ANNUAL AVERAGE

	Passenger Car	Single-Unit Truck	Combination Truck	Other Vehicles*
Passenger Car	5,595	564	1,694	5,151
Single-Unit Truck		21	57	258
Combination Truck			122	742
Other Vehicles*				1,451

Total Two-Vehicle Accidents = 15,655

*Other vehicles included motorcycles, buses, light trucks and vans, unknown vehicle type, and special vehicles.

Source: FARS (1979-1980)

The distribution of accidents by the severity of their results is shown in Table III-6. Large-truck accidents appeared to result more often in fatalities or property damage than did accidents that did not involve large trucks.

The distribution of fatal and nonfatal injury rates among persons involved in all motor vehicle accidents is presented in Table III-7. As expected, pedestrians, bicyclists, and motorcyclists were far more often injured than were vehicle occupants when they were involved in accidents. However, this could reflect that accidents or the involvement of such persons in accidents often went unreported when they were uninjured. The proportion of passenger car occupants who were injured was more than double that of large-truck occupants, yet when injuries did occur, truck occupants were nearly three times more likely to be fatally injured than were car occupants.

Calculations shown in Table III-8 indicate that in multiple-vehicle accidents involving large trucks, the injury rate was more than four times greater for the occupants of "other" vehicles than for those of large trucks (223 versus 52) and the fatality rate was more than seven times greater for "other" vehicle occupants than for occupants of large trucks (8.9 versus 1.2). Also noteworthy were the relatively high injury and fatality rates (238 and 8.6, respectively) calculated for occupants of large trucks in single-vehicle accidents as compared to multiple-vehicle accidents.

Table III-9 shows the annual average for 1979-1980 for occupant-fatality mix in two-vehicle fatal accidents in which a total of 18,571 persons were killed--41 percent of all traffic fatalities in 1979-1980. Sixty-eight percent of them were passenger car occupants and only 2 percent were truck occupants. In collisions of cars with large trucks, 97 percent of the fatally injured were occupants of the passenger car. Thus, when a passenger car was involved in a collision with a large truck which resulted in a fatality, occupants of the car were about 29 times more likely to be killed than were the occupants of the truck.

TABLE III-6

PERCENT DISTRIBUTION OF ACCIDENTS BY SEVERITY
1979-1980 ANNUAL AVERAGE

Accident Severity	All Traffic Accidents	All Large-Truck Accidents	All Non-Large-Truck Accidents
Fatal[1]	0.7	1.4	0.6
Injury[2]	33.3	25.7	33.7
Property Damage Only[2]	60.5	68.9	60.0
Unknown[2]	5.7	3.7	5.8

Sources: [1]FARS (1979-1980)
[2]NASS (1979-1980)

TABLE III-7

INVOLVED AND INJURED PERSONS IN ALL ACCIDENTS
1979-1980 ANNUAL AVERAGE

	Persons Involved[1]	Persons Injured[1]	Persons Injured Per 1000 Involved Persons	Persons Fatally Injured[2]	Fatally Injured Per 1000 Injured Persons
Motor Vehicle Occupants					
Passenger Cars	13,979,000	2,574,000	184	27,623	11
Light Truck or Van	2,132,000	386,000	181	6,508	17
Single-Unit and Combination Trucks	480,000	43,000	90	1,346	31
Motorcyclists	221,000	182,000	824	5,017	28
Occupants of Other Vehicles	686,000	67,000	98	1,425	21
Occupants of Vehicles Not in Transport	65,000	14,000	215	132	9
Non-Occupants					
Pedestrians	127,000	113,000	890	8,081	72
Pedalcyclists	87,000	79,000	908	948	12
TOTALS	17,777,000	3,458,000		51,080	

Sources: [1]NASS (1979-1980)
[2]FARS (1979-1980)

TABLE III-8

INJURIES OCCURRING IN ACCIDENTS INVOLVING LARGE TRUCKS*
1979-1980 ANNUAL AVERAGE

	Single Vehicle	Multiple Vehicle**
Number of Accidents	88,000	290,000
Number of Truck		
Occupants	105,000	368,000
Number Injured	25,000	19,000
Occupant Injury Rate+	238	52
Number Killed++	906	432
Occupant Fatality Rate+	8.6	1.2
Number of Other Vehicles		
Occupants	-	457,000
Number Injured	-	102,000
Occupant Injury Rate+	-	223
Number Killed++	-	4,065
Occupant Fatality Rate+	-	8.9

*Does not include truck accidents involving pedestrians and motorcycles.
**Two or more vehicles involved.
+Per 1,000 accident-involved occupants
++1979-1980 data from FARS

Source: NASS (1979-1980)

TABLE III-9

OCCUPANT FATALITY MIX IN TWO-VEHICLE FATAL ACCIDENTS
1979-1980 ANNUAL AVERAGE

	Vehicle in Which Fatality Occurred			
Other Vehicle In Accident	Passenger Car	Single-Unit Truck	Combination Truck	Other Vehicles*
Passenger Car	6,805	27	64	2,759
Single-Unit Truck	639	22	12	272
Combination Truck	2,016	50	141	841
Other Vehicles*	3,232	18	34	1,639

Total Occupant Fatalities for two-vehicle accidents = 18,571

*Other vehicles included motorcycles, buses, light trucks and vans, unknown vehicle type, and special vehicles.

Source: FARS (1979-1980)

PAST TRENDS

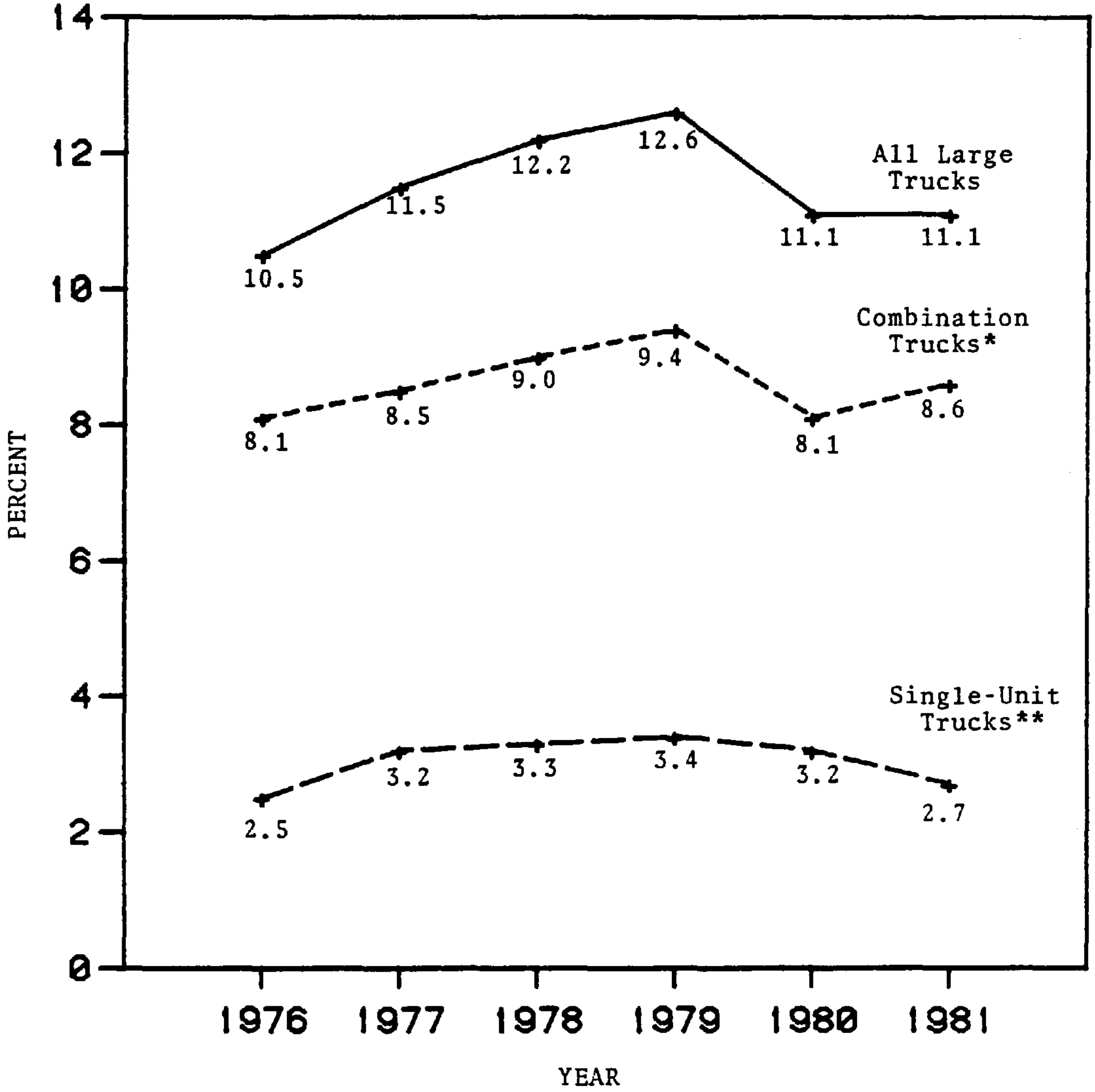
The best data available for examining past trends in accidents involving large trucks are the FARS tabulations for 1976-1981. The six-year curves plotted in Figure III-2 demonstrate that the proportion of fatal accidents that involved combination trucks increased steadily from 1976 to 1979 and then decreased in 1980 and increased slightly in 1981 while the proportion for single-unit trucks remained relatively constant until 1980 and then decreased slightly in 1981.

The number of fatal accidents and the number of fatalities by vehicle type for the same six years are contained in Tables III-10 and III-11, respectively. In both tables the vehicle types are not mutually exclusive; that is, an accident that involved both a truck and a passenger car, are included in each category. The annual fatal accident count increased each year from 1976 to 1980 but the annual rate of change declined from 6.2 percent to 0.1 percent. Fatal accidents decreased nearly 3 percent in 1981. Fatal accidents that involved passenger cars increased from 1976 to 1978, then declined from 1979 to 1981. Fatal accidents involving large trucks increased from 1976 to 1979, declined substantially (11.3 percent) in 1980 and declined another 2.7 percent in 1981. This recent decline in fatal accidents may be at least partially attributable to reductions in vehicle miles of travel. These patterns are virtually the same with respect to the number of fatalities (Table III-11).

Because these trends showed a change in pattern, a further examination was made. Figure III-3 graphically displays the rise and fall since 1976 in the rate of change in the number of all fatal accidents and those that involved passenger cars, combination trucks, and single-unit trucks. The percentages used are contained in Table III-12. The two truck types both experienced a much larger percent increase in fatal accident rate of change than did passenger cars since 1976. The rate of change peaked in 1979, then declined in 1980 for all categories except for a slight increase for the total of all fatal accidents. The drop in the rate of change in 1980

FIGURE III-2

FATAL LARGE-TRUCK ACCIDENTS IN
RELATION TO ALL FATAL U.S. TRAFFIC ACCIDENTS
(1976-1981)



*Combination trucks included all articulated trucks and truck tractors with no trailers (bobtail)

**Single-unit trucks included all non-articulated trucks with a known or unknown gross vehicle weight

Source: FARS (1976-1981)

TABLE III-10

FATAL ACCIDENT EXPERIENCE FOR 1976-1981

	Year					
	1976	1977	1978	1979	1980	1981
All Fatal Accidents	39,747	42,211	44,433	45,223	45,284	43,980
Fatal Accidents Involving*:						
-- Passenger Cars	29,533	30,791	32,028	31,912	31,550	30,735
-- Combination Trucks	3,226	3,575	4,012	4,251	3,679	3,778
-- Single-Unit Trucks	1,003	1,344	1,479	1,526	1,441	1,197
-- All Large Trucks	4,173	4,838	5,399	5,679	5,040	4,905

*Accidents are not mutually exclusive; e.g., an accident involving a combination truck and a single-unit truck is counted in both categories.

Source: FARS (1976-1981)

TABLE III-11

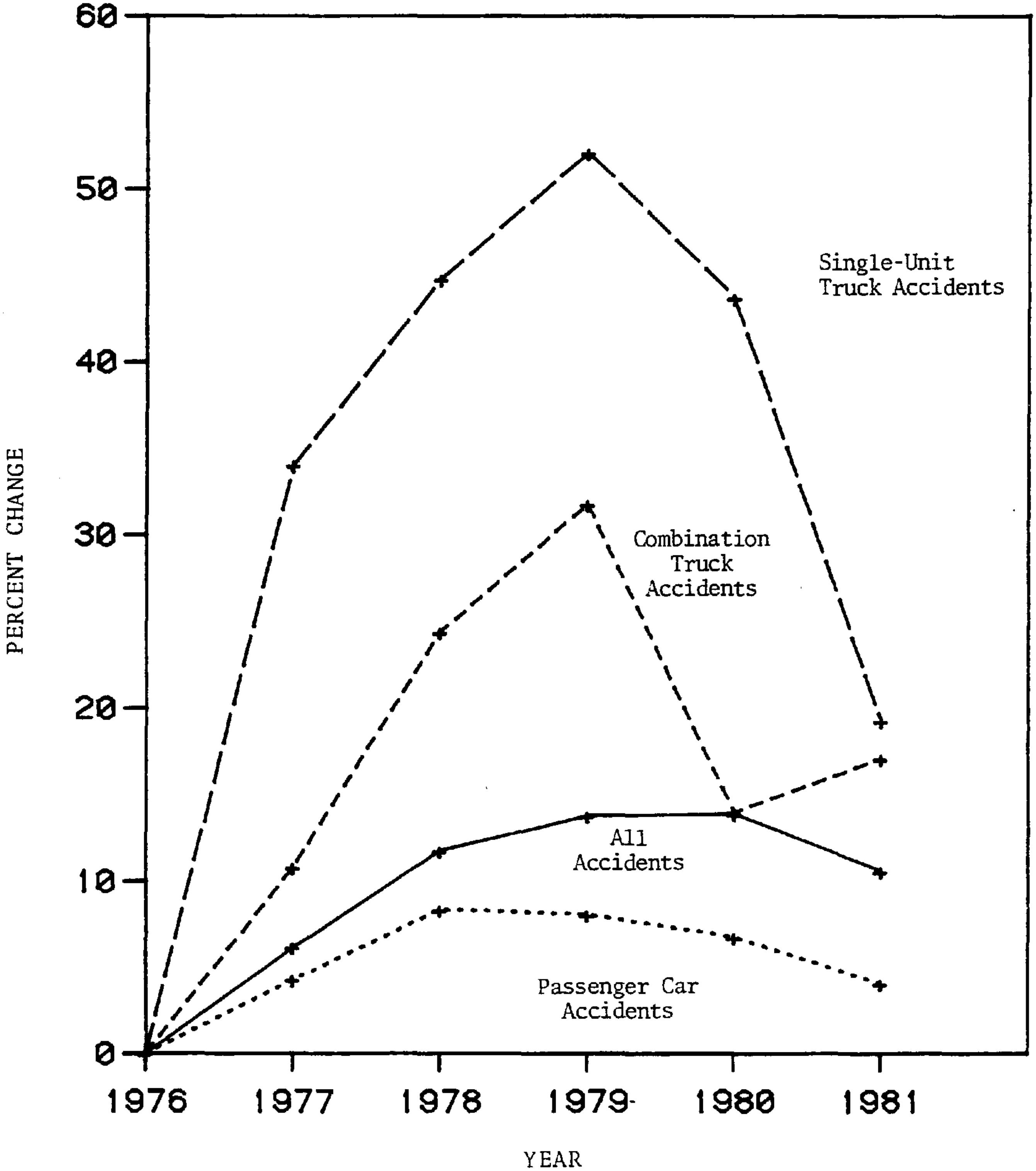
FATALITIES FOR 1976-1981

	Year					
Number of Fatalities in:	1976	1977	1978	1979	1980	1981
-- All Accidents	45,523	47,878	50,331	51,093	51,091	49,268
-- Passenger Car-Related Accidents	34,472	35,567	37,006	36,740	36,373	35,109
-- Combination Truck-Related Accidents	3,909	4,260	4,759	5,090	4,412	4,496
-- Single-Unit Truck-Related Accidents	1,155	1,547	1,695	1,726	1,653	1,374
-- All Large Truck-Related Accidents	4,996	5,717	6,350	6,696	5,968	5,779
Occupant Fatalities in All Large Truck-Related Accidents for:						
-- Trucks	1,130	1,285	1,393	1,431	1,261	1,131
-- Passenger Cars	2,497	2,899	3,204	3,318	2,875	2,911
-- Other Motor Vehicles	877	1,022	1,146	1,292	1,203	1,194

Source: FARS (1976-1981)

FIGURE III-3

PERCENTAGE CHANGE IN FATAL ACCIDENTS
INVOLVING SELECTED VEHICLE TYPES SINCE 1976



Source: FARS (1976-1981)

TABLE III-12

PERCENTAGE CHANGE RELATIVE TO 1976 ACCIDENT EXPERIENCE

	Year				
	1977	1978	1979	1980	1981
All Fatal Accidents	6.2	11.8	13.8	13.9	10.6
Fatal Accidents involving:					
-- Passenger Cars	4.3	8.4	8.1	6.8	4.1
-- Combination Trucks	10.8	24.4	31.8	14.0	17.1
-- Single-Unit Trucks	34.0	44.8	52.1	43.7	19.3
-- All Large Trucks	15.9	29.4	36.1	20.8	17.5
Number of Fatalities in:					
-- All Accidents	5.2	10.6	12.2	12.2	8.2
-- Passenger Car-Related Accidents	3.2	7.4	6.6	5.5	1.8
-- Combination Truck-Related Accidents	9.0	21.7	30.2	12.9	15.0
-- Single-Unit Truck-Related Accidents	33.9	46.8	49.4	43.1	19.0
-- All Large Truck-Related Accidents	14.4	27.1	34.0	19.5	15.7
Occupant Fatalities in All Large Truck-Related Accidents for:					
-- Trucks	13.7	23.3	26.6	11.6	0.1
-- Passenger Cars	16.1	28.3	32.9	15.1	16.6
-- Other Motor Vehicles	16.5	30.7	47.3	37.2	36.1
VMT for all Vehicles (FHWA)	4.6	10.1	9.0	9.0	*

*1981 VMT estimates not available

Source: FARS (1976-1981)

was greatest for combination trucks and least for passenger cars. The drop in 1981 is greatest for single-unit trucks with a slight rise for combination trucks.

Although total travel for these vehicle groups probably influenced the fluctuations, the changes in the rates by which fatal accidents increased and decreased was greater than the change in total vehicle miles of travel (VMT), which continued to increase from 1975 to 1978, when it began to decrease (Table III-13). Estimates for 1980 indicate that total vehicle miles travelled was continuing downward. Considered separately, vehicle miles travelled by passenger cars and combination trucks have also decreased gradually since 1978 and 1979, respectively. Figure III-4 graphically illustrates the changes in vehicle miles travelled since 1975 by combination trucks, passenger cars, and all vehicles. The rate of change for combination trucks has been more rapid than that for passenger cars or all vehicles. Changes in the frequency of fatal accidents has tended to follow changes in exposure as measured by VMT.

Another perspective on accidents involving large trucks was obtained by examining the relative risk of death to occupants in two-vehicle accidents in which fatalities occurred. Table III-14 shows the ratio of occupant fatalities in Vehicle A to the occupant fatalities in Vehicle B when the two vehicles are involved in a fatal accident. During 1979 and 1980, collisions between passenger cars and large trucks resulted in a much higher relative risk to passenger car occupants than other types of collisions. As indicated in Table III-14, the risk of death to occupants in passenger-car/large-truck collisions increased steadily from 1977 to 1980, possibly reflecting the increased number of smaller passenger cars.

FUTURE TRENDS

Forecasting represents an attempt to look forward through a rearview mirror. At present, the valid data needed to forecast large-truck accidents for the

TABLE III-13

ESTIMATED VEHICLE MILES OF TRAVEL AND PERCENTAGE INCREASE SINCE 1975 FOR SELECTED VEHICLE TYPES*

	Year					
	1975	1976	1977	1978	1979	Preliminary 1980
Passenger Cars						
VMT (billions)	1,006.9	1,054.1	1,094.0	1,141.8	1,130.0	1,111.8
% increase since 1975	-	4.7	8.7	13.4	12.2	10.4
Trucks** (excluding combination trucks)						
VMT (billions)	258.9	282.6	304.0	329.7	323.1	343.9
% increase since 1975	-	9.2	17.4	27.3	24.8	32.8
Combination Trucks						
VMT (billions)	45.9	48.9	51.6	55.0	57.7	53.6
% increase since 1975	-	6.5	12.4	19.8	25.7	16.8
All Vehicles						
VMT (billions)	1,327.7	1,402.4	1,467.0	1,544.7	1,529.1	1,528.0
% increase since 1975	-	5.6	10.5	16.3	15.2	15.1
Passenger Cars VMT as % of all VMT	75.8	75.2	74.6	73.9	73.9	72.8
Trucks** (excluding combination trucks) VMT as % of all VMT	19.5	20.2	20.7	21.3	21.1	22.5
Combination truck VMT as % of all VMT	3.5	3.5	3.5	3.6	3.8	3.5

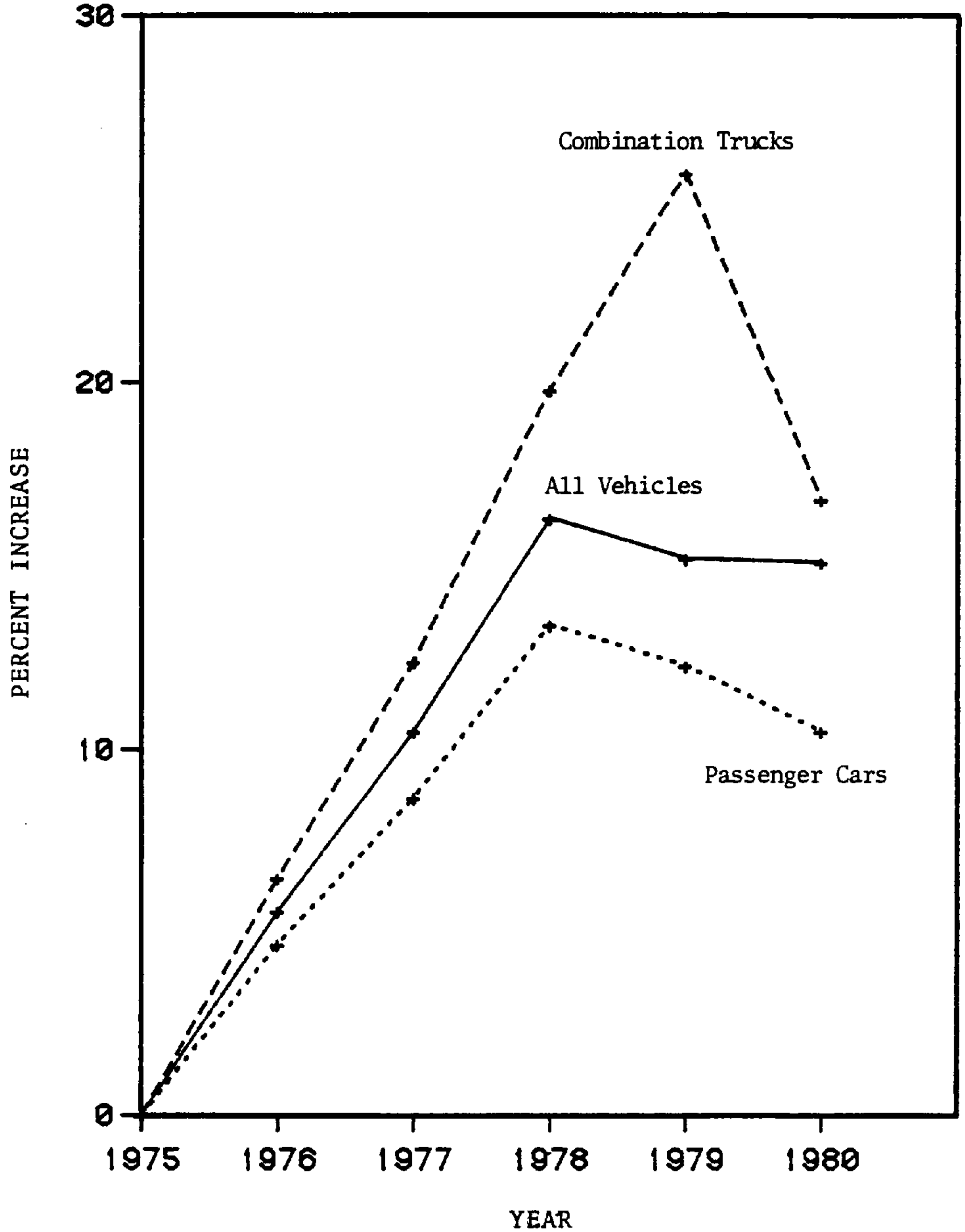
*These estimates represent an update of earlier estimates published in "Highway Statistics" and are based on more recent information regarding truck travel.

**This category includes light pickups and vans and other trucks not identified as combinations.

Source: FHWA, Highway Statistics Division (1982)

FIGURE III-4

PERCENT INCREASE IN VMT SINCE 1975



Source: FHWA, Highway Statistics Division (1982)

TABLE III-14

RELATIVE RISK OF DEATH FOR OCCUPANTS IN TWO-VEHICLE FATAL ACCIDENTS

Type of Collision		Year 1977		1978		1979		1980	
Vehicle A	-- Vehicle B								
Passenger Car	-- Single-Unit Truck	16.7	22.9	17.8	25.2	22.9	28.6	25.6	30.6
	-- Combination Truck	26.0		28.9		30.8		32.9	
	-- Other Vehicles*	1.16		1.24		1.18		1.16	
Other Vehicles*	-- Single-Unit Truck	11.9	18.4	16.9	15.3	12.9	20.7	18.7	22.2
	-- Combination Truck	21.8		14.9		25.8		23.7	
Single-Unit Truck	-- Combination Truck	2.3		2.2		4.3		3.7	

NOTE: This table illustrates the ratio of occupant fatalities in Vehicle A to the occupant fatalities in Vehicle B when the two vehicles were involved in fatal accidents. For example, in 1979, when a passenger car was involved in a fatal accident with a large truck, occupants of the car were 28.6 times more likely to have been killed than occupants of the truck.

*Other vehicles included motorcycles, buses, light trucks and vans, unknown vehicle type, and special vehicles.

Source: FARS (1977-1980)

1980s and beyond do not exist. Consequently this section is less a forecast than a sketch of the possible future portents of available information about exposure, the changing vehicle mix, and past accident trends.

The speculative nature of these projections is heightened by the possible applications of technologies to improve automobile or truck crashworthiness, increases in safety belt use, major modal shifts in cargo transportation, and other unknowable changes that bedevil prognostication and cloud crystal balls.

Distribution and delivery of goods to serve the needs of urban centers can be expected to continue. Thus, vehicle miles travelled by large trucks is likely to increase as urban centers expand during the next decade. Comparison of the changes in projected VMT travel by different types of vehicles from 1977 to 1990 (Table III-15) indicates a large increase in travel projected for combination trucks (63 percent) with a much smaller increase projected for single-unit trucks (16 percent). Passenger car travel from 1977 to 1990 is projected to increase by 30 percent overall; vehicle miles of travel by large automobiles is expected to decrease by 32 percent while that by small automobiles is expected to increase more than threefold. It should not be expected that changes in miles travelled by all vehicles will be a simple, linear function. In fact, estimated vehicle mileage has been decreasing since 1978 (Table III-13), but it is anticipated that increases in overall travel will take place by 1990.

Past trends indicate that the change in fatal accidents has been greater than the change in vehicle miles travelled (Table III-12). The rate of fatal accidents per VMT for all vehicles increased 4.6 percent from 1976 to 1980. Rates for fatal accidents involving combination trucks increased 4.1 percent from 1976 to 1980 while the rate of fatal accidents involving passenger cars generally remain constant (1 percent increase). Even if these rates were to remain constant at 1978 levels (the most recent year that both fatal-accident and VMT data are available for both large trucks and the subgroups of

TABLE III-15

COMPARISON OF PROJECTED VEHICLE MILES OF TRAVEL (MILLIONS)
BY VEHICLE CLASS

Vehicle Class	1977 VMT	1985 VMT	1990 VMT	Percent Change 1977-1990
Passenger Vehicles				
Autos				
Large	839,301	670,417	571,759	-32%
Small	219,247	497,598	805,477	+267%
Total	1,058,548	1,168,015	1,377,236	+30%
Motorcycles	11,490	18,613	30,158	+162%
Buses				
Intercity	1,109	1,109	1,109	
Other	4,791	5,004	5,039	
Total	5,900	6,113	6,148	+4%
Pickups and Vans	249,798	397,906	476,002	+91%
Total Passenger Vehicles	1,325,736	1,590,647	1,889,544	+43%
Trucks				
Single-Unit				
Under 26,000 lbs.	39,000	39,000	39,000	
Over 26,000 lbs.	15,205	20,131	23,934	
Total	54,205	59,131	62,934	+16%
Combinations				
Under 50,000 lbs.	7,432	9,693	11,450	
50,000-70,000 lbs.	11,920	15,104	17,843	
70,000-75,000 lbs.	14,211	20,088	23,969	
Over 75,000 lbs.	17,994	25,686	30,706	
Total	51,557	70,571	83,968	+63%
Total Trucks	105,762	129,702	146,902	+39%
All Vehicles	1,431,498	1,720,349	2,036,446	+42%

Source: FHWA Cost Allocation Study (1982) combination and single-unit trucks), the proportion of fatal large-truck accidents can be expected to increase from 12 percent in 1978 to 14 percent of all fatal accidents by 1990. Likewise, the proportion of fatal combination-truck accidents in 1990 can be expected to increase from 9 percent in 1978 to over 12 percent of all fatal accidents, while the proportion of fatal single-unit truck accidents will remain unchanged from the 1978 level.

A change in the amount of vehicle miles travelled does not necessarily reflect a similar change in overall vehicle population. VMT for all vehicles decreased from 1978 to 1979 (Table III-13), but the registered vehicle population increased (FHWA, 1979). This resulted in lower annual mileage driven per vehicle. The same pattern was reflected for passenger cars, considered separately: more passenger cars were registered in 1979, but on average each was driven less. If it can be assumed, however, that this reduction in vehicle usage is not a long-term trend and that average use of vehicles will remain somewhat constant during the decade, then increases in VMT imply corresponding increases in the number of registered vehicles. In this event, present roadway facilities will have to accommodate more vehicles and the likelihood of collisions will increase.

Small cars have begun to dominate the new car market. If this continues as expected, by the mid-1980s small cars will account for the majority of cars on the road (Ramsett and Sherrer, 1981). Assuming increases in overall vehicle population, there are likely to be more collisions involving heavier vehicles and consequent increases in severity rates because of the larger proportion of smaller and lighter cars on the road.

Also, there has been a shift in recent decades in the type of crashes in which the majority of deaths occur. During the 1950s the majority of deaths occurred in single-vehicle crashes. By the 1970s the majority of deaths were in multiple-vehicle crashes (Boehly and Lombardo, 1981). This trend, and the likelihood of more collisions between vehicles of substantially different sizes and weights, will certainly contribute to increased risk to the occupants of small cars. Compacts and subcompacts accounted for about 46 percent of the cars on the road in 1980, but occupants of these cars accounted for 57 percent of the deaths in fatal car-to-car accidents, and 44 percent of the deaths in fatal car-to-large-truck accidents (FARS data, 1980). If and when small cars become the majority population of all cars, it is reasonable to expect that the proportion of small-car occupants killed in two-vehicle crashes and the frequency of small-car/large-truck crashes will increase significantly.

SECTION IV
CONTRIBUTING FACTORS

This section examines available data on driver, vehicle, and highway/environmental factors which are believed to contribute to accidents involving large trucks and injuries resulting from these accidents. It begins with a brief discussion of approaches to determining accident causation. This discussion attempts to place the complex relationships among the multiple factors within the perspective of a rationally organized pattern.

APPROACHES TO ACCIDENT CAUSATION

The traditional debate on the causes of traffic accidents has been whether the highway, the vehicle, or the driver "caused" a given accident. This method of determining cause frequently features a subjective choice of a precipitating factor--often the last of a set of sequential circumstances or conditions without which the accident presumably would not have occurred. The following examples illustrate simplistic accident situations:

Causal Agent		Example
Highway/ Environment	-	"Potholes" on curved section of roadway with superelevation inadequate for design speed.
Truck	-	Sudden brake failure.
Driver	-	Failure to yield right-of-way despite a clear view of oncoming vehicles.

The three examples represent situations most people believe should not be allowed to exist. However, it is possible to conceive of methods to eliminate these situations and the resulting accidents. Roads should be well-planned and maintained; vehicles should be built to perform consistently under normal use and with regular maintenance; drivers should behave responsibly and with consideration for the rights of others. Theoretically, there could be road systems without hazards, vehicles designed to guarantee fail-safe operation, and methods of assuring driver competency in all situations before being allowed to drive. While technically possible, such measures are typically not realistic. They are listed here because they represent the quite rare accident circumstance--the single cause. The single-cause approach in the overwhelming majority of traffic accidents represents a gross oversimplification. The real world is a far more complex system of multiple variables.

The alternative approach is to consider several factors as operating jointly. Using this concept, an accident occurs only when a hazardous condition in one or more factors exceeds the compensatory ability or inherent performance characteristics of the others.

The choice between the two approaches depends on the purpose of the quest for accident causes. The single-cause approach might be appropriate for the adjudication of individual accident cases, for example in the settlement of insurance claims or the prosecution of violations of the law, but it is the multiple-factor approach which must be adopted when the <u>relative</u> contribution of individual factors to accident probability is sought by statistical inference. In the context of this report such calculations are necessary to arrive at an identification of the "causes" of large-truck accidents--that is, an identification of those <u>combinations of factors</u> in the presence of which high probability exists that various types of accidents involving large trucks will occur.

When accident-causation research is viewed as the evaluation of factors, it is accompanied by certain requirements, regardless of the analytical techniques to be employed. These are:

- Precise formulation of the specific questions to be answered or hypotheses to be tested;

- o Classification of accident types--that is, identification of the types of accidents to which the questions apply; and

- o Acquisition of appropriate, detailed, and accurate accident data.

The fulfillment of these three requirements is essential for selecting pertinent factors and to adequately control for the prevalence of these factors in real-world accidents. An understanding of the causal system responsible for accidents involving large trucks requires comparing accidents for consistent factor-combinations with and without the safety-related features being studied.

For many applications, it is also necessary to establish relevant accident rates by acquiring and applying of pertinent exposure data, the most commonly used being vehicle miles of travel (VMT).

It is important to recognize that accident, injury, and fatality rates are purely descriptive. They do not imply cause, nor do they provide answers. Rather, they provide clues that indicate where problems exist and where additional research is needed. Their single purpose is to provide a standard basis for comparison. They become predictive only under the assumption that none of the unknown factors in the causal system changes its level of contribution to the accidents being studied.

The objective of accident-causation research is to identify safety problems and place them into perspective so that effective countermeasures subsequently can be developed, implemented, and evaluated. Conclusions derived from accident and corresponding exposure or travel data are essential to identify problem areas, to point directions toward the development of promising countermeasures, and to evaluate the effectiveness of implemented countermeasures. Achievement of this objective can be enhanced through the use of mathematical models, controlled laboratory and test-track experiments, and field evaluations. Accident data alone cannot provide an adequate basis for such research. To fully answer questions about the relative effectiveness among various guardrail designs or brake system designs, for example, controlled laboratory or test-track experiments or computer simulations must be used to provide the information not contained in accident data. For a further discussion of supplemental safety research to accident data systems, see Appendix C.

The accident-causation approach used as the basis for this report emphasizes the role that multiple factors play in accident causation. Successful efforts to prevent accidents have all relied on systematic and concurrent efforts to address all factors involved. Efforts which stop at a determination of the precipitating or "trigger" event in the accident chain produce little useful information for the identification of the many possible underlying factors that contribute to a particular crash.

Continued improvements to truck safety will depend upon widespread acceptance and application of proven research and development techniques which address this broad spectrum of factors.

DRIVER-RELATED CONTRIBUTING FACTORS

It is commonly agreed that the demands and skills required in driving large trucks are more complex than those required in the routine driving of automobiles (Waller et al., 1976 and Moe et al., 1973). Because these larger and heavier vehicles are required to operate in mixed traffic composed primarily of vehicles with quicker response characteristics, drivers of large trucks must compensate for the relative awkwardness of their vehicles. Such compensation requires greater distances for passing, stopping, turning and accelerating, and a consequent need for more effective anticipation of approaching situations. In addition, maneuvers with large trucks are more complex than those with passenger cars. Large trucks also tend to operate closer to the design limits of both the vehicle and the highway. This results in narrower margins for error, particularly for recovery of an errant vehicle. Thus, the demand for attention and the precision required in most truck-driving situations make the truck driver a critical variable in the truck-accident equation.

"Driver error" has often been cited as a major link in the causal chain in accidents involving large trucks (Shinar, 1979 and Washington State, 1980). Shinar analyzed 161 in-depth investigations of accidents that involved large trucks and found that 8 of the 10 accident "causes" cited most frequently were related to driver error. The remaining two "causes" were related to the highway environment. Washington State data based on police-reported information (Table IV-1) indicate that inattention and negligence most frequently "caused" accidents that involved a large truck and another vehicle. The truck driver was the causal factor named in 62 percent of the accidents compared to 31 percent for the other driver. Defective truck equipment was cited in 6 percent of the accidents. While "driver error" may be a major identifiable event which immediately preceded the accident, the true "causes" of the accident must be traced to multiple factors and conditions, including driver judgments, that led to the accident.

TABLE IV-1

PERCENT DISTRIBUTION OF APPARENT CAUSES OF LARGE-TRUCK ACCIDENTS*

Apparent Cause	Truck Driver or Truck		Other Vehicle Drivers or Other Vehicle	
	Urban	Rural	Urban	Rural
Inattention	47.3	37.3	40.8	28.8
Negligence	24.2	34.8	33.9	36.0
Reckless	0.7	1.7	2.9	3.1
DWI	2.0	2.1	8.4	10.1
Following too Close	6.0	4.1	4.4	3.9
Over Centerline	2.0	3.2	1.9	8.6
Improper Turn	9.9	3.9	3.6	3.9
Apparently Asleep	0.8	3.0	1.3	0.9
Operating Defective Equipment	7.1	9.9	2.8	4.7
Total Number of Accidents	1,672	1,599	869	674

*The 4,814 accidents analyzed involved the collision of a truck with another vehicle.

Source: Washington State (1980)

This section attempts to identify driver-related factors that contribute to truck accidents and fatalities, including the driver's age, experience, training, qualification, medical condition, fatigue, alcohol use, and use of other drugs.

Several sources frequently referred to in this report are D.D. Wyckoff's book, Truck Drivers in America, published in 1979 and a study by BioTechnology, Inc. entitled, "The Effect of Truck Size and Weight on Accident Experience and Traffic Operations" (Vallette et al., 1981). Wyckoff analyzed interview and voluntary survey responses by truck drivers, and it is appropriate to note that a number of the Wyckoff analyses and conclusions have been criticized on methodological grounds (Raven, 1979). Although his information is subject to sampling bias and other limitations, if it is not useful as proof of accident causation it is indicative of which driver factors may merit closer attention. The BioTechnology study report provides accident and matching exposure information for large trucks of various sizes and weights. It contains the only available accident-exposure information for a broad spectrum of contributing factors described in this report. The BioTechnology study report was extensively reviewed within and outside the Department of Transportation by interested groups from a State Government, truck manufacturers, the trucking industry, labor organization, and safety and research organizations. Not all of the groups agreed with the findings and the contents of the research report do not reflect an endorsement by any of these groups.

Age, Experience, and Training

Numerous studies and data have provided statistics on the distribution of large-truck accidents by age of the driver. Some of these are listed in Table IV-2. Age groupings are those used by the BMCS.

DISTRIBUTION OF ACCIDENT-INVOLVED DRIVERS OF LARGE TRUCKS BY AGE AND AGE DISTRIBUTION OF ALL TRUCK DRIVERS
(percent)

<table>
<tr><th></th><th colspan="9">ACCIDENTS</th><th>FATAL ACCIDENTS</th><th></th></tr>
<tr><th rowspan="2">DRIVER AGE+</th><th rowspan="2">BMCS[1] 1978</th><th rowspan="2">Six State[2] 1976-77</th><th colspan="2">North Carolina[3] 1973</th><th colspan="2">California[4] 1970-71</th><th rowspan="2">Texas[5] 1973-77</th><th rowspan="2">NASS[7] 1979-80</th><th rowspan="2">FARS[8] 1979-80</th><th rowspan="2">1977 Survey of Age of Truck Drivers[6]</th></tr>
<tr><th>Large Trucks*</th><th>Medium Trucks</th><th>Single Unit</th><th>Combinations</th></tr>
<tr><td>less than 20</td><td>0.8</td><td>2</td><td>2.8</td><td>8.6</td><td>5.2</td><td>0.9</td><td>2.2</td><td>3.6</td><td>3.4</td><td>--</td></tr>
<tr><td>20-24</td><td>11.5</td><td rowspan="2">30</td><td>19.0</td><td>24.0</td><td rowspan="2">30.2</td><td rowspan="2">22.9</td><td>13</td><td>13.8</td><td>13.5</td><td>3.0</td></tr>
<tr><td>25-29</td><td>17.4</td><td>17.4</td><td>15.3</td><td rowspan="2">34</td><td>13.4</td><td>17.4</td><td>10.2</td></tr>
<tr><td>30-34</td><td>16.7</td><td rowspan="2">30</td><td>14.1</td><td>11.2</td><td rowspan="2">21.3</td><td rowspan="2">27.8</td><td>16.6</td><td>15.1</td><td>15.6</td></tr>
<tr><td>35-39</td><td>14.2</td><td>12.4</td><td>8.4</td><td rowspan="2">24.9</td><td>10.8</td><td>13.2</td><td>14.9</td></tr>
<tr><td>40-44</td><td>12.1</td><td rowspan="2">20</td><td>10.5</td><td>6.1</td><td rowspan="2">17.0</td><td rowspan="2">25.0</td><td>12.3</td><td>10.7</td><td>17.3</td></tr>
<tr><td>45-49</td><td>10.3</td><td>9.0</td><td>7.6</td><td rowspan="2">18.0</td><td>10.8</td><td>8.5</td><td>16.6</td></tr>
<tr><td>50-54</td><td>8.2</td><td rowspan="2">15</td><td>5.7</td><td>6.6</td><td rowspan="2">12.3</td><td rowspan="2">13.5</td><td>6.6</td><td>8.5</td><td>11.5</td></tr>
<tr><td>55-59</td><td>5.4</td><td>3.4</td><td>5.0</td><td rowspan="2">7.7</td><td>3.4</td><td>5.9</td><td>8.5</td></tr>
<tr><td>60 or more</td><td>2.5</td><td>3</td><td>1.7</td><td>3.8</td><td>4.5</td><td>2.9</td><td>4.4</td><td>3.7</td><td>2.4</td></tr>
<tr><td>Not stated</td><td>0.9</td><td>--</td><td>3.9</td><td>3.0</td><td>9.5</td><td>7.0</td><td>--</td><td>4.3</td><td>0.2</td><td>--</td></tr>
</table>

+Age groupings are those used by BMCS
*This study defined large trucks as three-axle trucks and combination trucks, and medium trucks as two-axle trucks more than 24,000 pounds GVW.

Sources:
[1]BMCS (1978)
[2]Vallette et al. (1981), six states of study were California, Maryland, Michigan, Nevada, Pennsylvania, and Texas
[3]Lohman and Waller (1975), age brackets differ by 1 year
[4]Zeiszler (1973)
[5]O'Day et al. (1980), combination trucks only
[6]Sanders (1977), age brackets differ by 1 year
[7]NASS (1979-1980) Annual Average
[8]FARS (1979-1980) Annual Average

A comparison of accident distributions by driver ages with a survey by Sanders (1977) indicated that drivers under 30 were involved in a disproportionately high percentage of both fatal and all accidents. Similar findings were reported by Green et al. (1980), Northrop et al. (1976), and Vallette et al. (1981). Vallette et al. matched accident data with exposure (VMT) data from surveys made at weighing stations and truck stops to develop accident rate distributions by driver age. Table IV-3 provides the results of this analysis. It clearly shows a trend, consistent for each truck type, of high accident rates for the younger age group, low for the middle age group, and somewhat high again for the older age group.

North Carolina and California data (Table IV-2) indicate that there were a greater percentage of young drivers involved in "medium" and single-unit truck accidents than were involved in combination-truck accidents. This reflects the situation shown by Vallette et al. (1981) that, in general, drivers of single-unit trucks are younger and less experienced than are drivers of combination trucks.

Table IV-2 further indicates that 17 percent of all large-truck drivers under age 25 are involved in fatal large-truck accidents and 17.4 percent in all large-truck accidents. Comparable data indicate that while young passenger car drivers (under age 25) account for 18.9 percent of the passenger car miles travelled, they represent 40.7 percent of all passenger car drivers involved in fatal passenger car accidents and 37.9 percent of all passenger car accidents.

Generally, while passenger car drivers under 25 are twice as likely to be involved in an accident as could be expected from their share of miles driven, drivers of trucks under age 25 were about six times more likely to be involved in an accident than would be expected if their accident experience were comparable to their proportion of the truck-driving population.

TABLE IV-3

ACCIDENT RATES* BY TRUCK DRIVER AGE
AND TRUCK TYPE

Driver Age Group	Single-Unit Trucks	Truck Type: Combination Trucks: Single Trailer	Double Trailer	All Trucks
Under 20	669	**	**	887
20-29	88	191	505	192
30-39	85	130	280	122
40-49	68	108	246	102
50-59	134	142	320	140
60+	122	194	384	196

*Accidents per 100 million vehicle miles of travel
**Exposure values not available to calculate rates

Source: Vallette et al. (1981)

Thus, it appears that drivers of large trucks under age 25 exhibit much more of a safety problem than their counterpart passenger car driver. Other differences between passenger car drivers and truck drivers by age group were much less dramatic (FARS data, 1979-1980, NASS, 1981 and Smith et al., 1981).

In Wyckoff's (1979) survey, truck drivers were questioned about their driving safety practices and performances (Table IV-4). The survey methodology used by Wyckoff has been criticized for being non-random and errors in calculating rates have been identified (Raven, 1979), but, if a bias did exist, drivers more prone to violate safety regulations could be expected to have been less cooperative. If this is true, the survey represents a conservative estimate. The survey indicated that drivers under the age of 25 drove at slightly higher speeds, misrepresented their logs more frequently, drove beyond the ten-hour limitation more often, and had more violations than did middle-aged or older truck drivers. Thus, by their own estimates, younger truck drivers appeared to take more and graver risks than older drivers.

Analysis by age group that fails to consider experience level is not sufficient to understand the rate of accident involvement of drivers. Different types of carriers (exempt, private, contract, and common) generally have different policies regarding the hiring of young and/or inexperienced drivers. For example, Table IV-5 shows that exempt carriers employ a higher proportion of drivers under age 25 than either private, contract, or common carriers.

NHTSA and BMCS are conducting a study scheduled to be completed in 1982 that will attempt to identify the reasons young and/or inexperienced drivers seem to be involved disproportionately in accidents (Reiss, 1982).

Little information is available on the number of drivers of large trucks who have received formal driving instruction. However, data reveal that many accident-involved drivers have not had formal driver education. 1979 NASS

TABLE IV-4

DRIVER SAFETY PRACTICES AND PERFORMANCE, REPORTED BY AGE

Item	Driver's Age: Under 25	25-50	Over 50
Cruising speed, mph	62.0	59.8	58.1
Percentage who regularly misrepresent logs	39.0	16.0	4.1
Percentage who regularly drive beyond the 10-hour limitation	36.1	12.0	2.7
Moving violation per 100,000 miles per year	1.3	0.7	0.3

Source: Wyckoff (1979)

TABLE IV-5

AGE OF DRIVERS, REPORTED BY TYPE OF OPERATION
AND REGULATORY STATUS (percent)

	Company Drivers				Owner-Operators			
Driver's Age	Exempt	Private	Contract	Common	Exempt	Private	Contract	Common
Under 25	16.85	5.80	4.80	0.79	11.00	NA	9.58	7.63
25-34	37.08	36.20	29.02	18.56	31.00	NA	5.46	28.25
35-44	33.71	35.50	30.48	31.90	33.00	NA	29.92	32.48
45-54	8.99	17.40	26.72	35.70	20.00	NA	18.82	22.46
Over 55	3.37	5.10	8.98	13.05	5.00	NA	6.22	9.18
Total	100.00	100.00	100.00	100.00	100.00	NA	100.00	100.00

Source: Wyckoff (1979)

data show that more accident-involved truck drivers (59 percent) than car drivers (45 percent) were reported as having no formal driver training. Only 15 percent of the accident-involved truck drivers had any kind of commercial driver education (Partyka, 1981).

While there is a trend towards greater use of formal driver training among younger truck drivers, a majority of the drivers surveyed in what may have been a biased (Wyckoff, 1979) sample had not received any formal training. Training programs usually include Federal requirements, log book procedures, and hours-of-service regulations. A current BMCS study is developing truck-driver training standards and a model curriculum covering regulatory requirements and driving skills. This material will be used to define minimum FMCSR training requirements (NPSRI, 1982).

Medical Condition

Accident researchers (Simpson et al., 1977; Janke et al., 1978; O'Brien, 1979; and Naughton and Waller, 1980) and concerned organizations (American Association for Automotive Medicine, and International Association for Traffic Medicine) have indicated that medical conditions which impair a person's ability to respond to a complex driving situation are a significant contributing factor to motor vehicle accidents. The share of highway accidents attributed to medical conditions has been estimated by Waller (1973) at approximately 15 percent of all accidents. Data on the medical condition of truck drivers involved in accidents are scarce. For example, the medical condition of drivers was reported to BMCS in less than 5 percent of all fatalities (BMCS data, 1978).

Both BMCS and State medical standards for truck drivers are primarily subjective in nature. Medical certification is based on a case-by-case assessment by an examining physician with overview responsibility by the motor carrier or the State department of motor vehicles. Essentially, physicians are asked to decide subjectively if a given driver's medical condition will present a safety risk when driving.

Studies by BMCS and NHTSA have established more objective medical standards for some conditions. In a BMCS report, "The Insulin-Dependent Driver" (1980), three aspects of the diabetic driver were studied: (1) severity of disease, (2) crash data associated with diabetic drivers (they experienced about twice the accident rate of non-diabetic drivers [Waller, 1973]), and (3) job tasks and life styles of the interstate truck driver. After consideration of all data and information, the BMCS decided to continue restricting insulin-dependent drivers from interstate commerce.

More detailed data are needed on medical conditions and their possible relationship to accidents involving large trucks. State officials and the BMCS also are increasingly concerned about possible liability resulting from licensing and regulating drivers with known medical conditions. More quantitatively defensible standards are needed.

BMCS plans to study further the relationship between driver medical condition and large-truck accidents. The research will be conducted in Canada where the national health plan offers an unique opportunity to survey the entire accident population and relate information from medical records to driver records. The results of a study of this nature should be applicable to the trucking industry in the United States.

Fatigue

Federal Motor Carrier Safety Regulations (FMCSR) restrict the driving time of interstate truck drivers to no more than ten hours following eight consecutive hours off duty. This regulation (FMCSR Section 395, Hours of Service of Drivers) was adopted because fatigue has been identified as a contributing factor in accidents.

The relationship of fatigue and hours-of-service to truck safety was the subject of considerable research in the 1970s. A two-phase study was conducted by Harris and Mackie (1972) and Mackie and Miller (1978). In Phase I drivers were observed during truck runs and accident statistics from selected carriers were related to length of time on the road when the accident occurred, the time of day, and the driver's age and experience level. Some of the results of Phase I, as reported by Harris and Mackie are as follows:

- Significant increases in driver errors and significant decreases in the level of alertness of drivers began to show as early as the fourth hour of driving time and generally increased throughout the trip except for a "recovery" effect near the end of the trip (Federal safety regulations permit 10 hours consecutive driving time);

- The frequency of accidents increased disproportionately after about seven hours of driving and remained significantly higher than "expected" for all driving times longer than seven hours;

- The effectiveness of rest breaks on driver performance and level of alertness varied with the amount of total trip time. The amount of recovery declined with each rest break. Drivers taking a third rest break, after about nine hours, showed not only no recovery but a further decline in alertness;

- The adverse effects of prolonged driving were evidently more pronounced for older drivers (aged 45 or more) than for younger drivers; and

- There were marked time-of-day variations in level of alertness. The lowest levels occurred for most drivers between 2 AM and 7 AM.

Phase II consisted of a nationwide survey of truck drivers regarding their trip patterns, an analysis of BMCS accident data, and field experiments of driver fatigue. Some findings reported by Mackie and Miller (1978) include:

- o More accidents than expected occurred after five hours of driving (Figure IV-1). About twice as many accidents per mile travelled occurred in the second half of the trip as in the first half;

- o About twice as many accidents occurred between midnight and 8 AM (66 percent) as in the other 16 hours of the day (Figure IV-2); and

- o Drivers on irregular schedules experienced more fatigue than drivers on regular schedules and the effects occurred earlier.

In general, the Phase II results supported those of Phase I:

- o Significant increases in driver errors and decreases in alertness occurred within the current ten-hour limit;

- o "Sleeper" drivers experienced more severe fatigue than relay drivers;

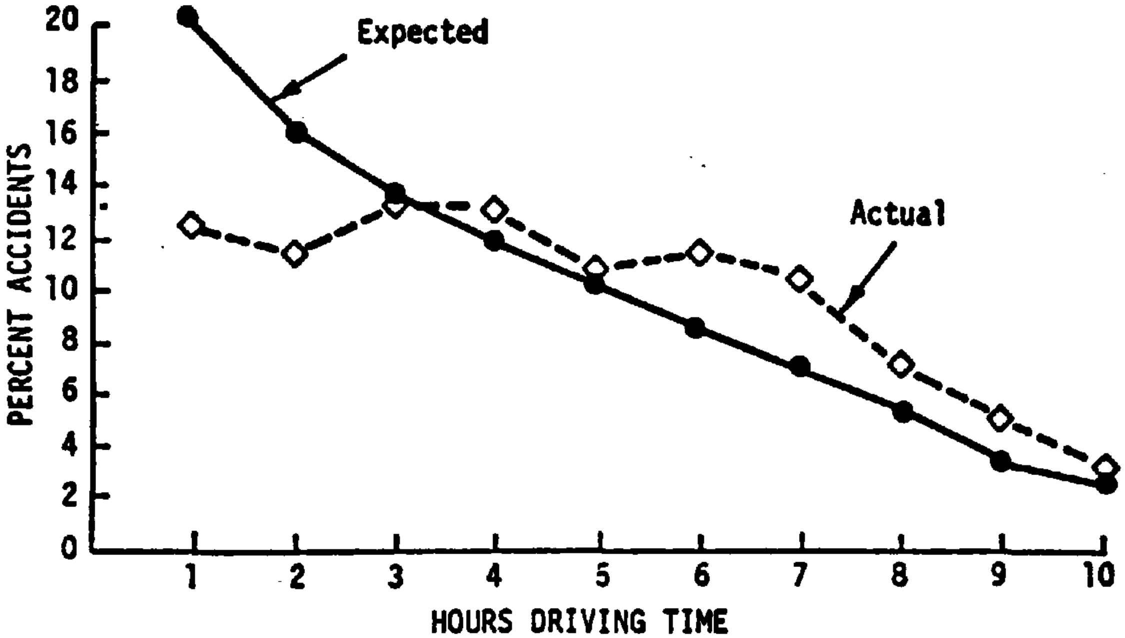
- o Cumulative effects of fatigue appeared sometime after four consecutive days on duty; and

- o Marked time-of-day variations in alertness levels strongly correlated with accidents in which the driver was judged to be drowsy, inattentive, or sleeping.

Results of another study of fatigue were reported by Hackman et al. (1978), who analyzed 1976 BMCS data on 5,200 accidents. The results were not as convincing in their correlation between hours of driving and probability of

FIGURE IV-1

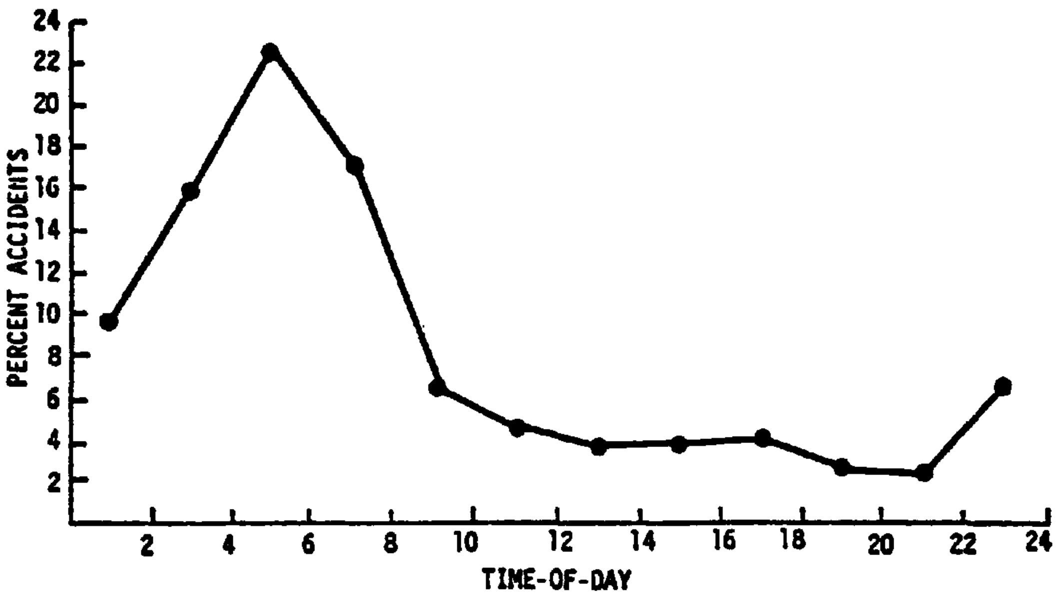
EXPECTED VERSUS ACTUAL PERCENTAGE
OF ACCIDENTS BY DRIVING TIME FOR
DOZING-DRIVER ACCIDENTS



Source: Mackie and Miller (1978)

FIGURE IV-2

PERCENTAGE OF ACCIDENTS BY TIME-OF-DAY
FOR DOZING DRIVERS



Source: Mackie and Miller (1978)

accident. They observed no consistent patterns in the data to imply that the number of driving hours alone were related to the frequency or severity of truck accidents. Other findings:

- o An increase was noted in both fatigue-related and other accidents around the destination point;

- o No consistent relationship was found between the length of the last extended rest and when the accident occurred; and

- o Proportionally more fatigue-related accidents occurred between 11 PM and 8 AM than all other time classifications.

Though it is not always possible to show a direct relationship between accidents and fatigue, it is possible to study performance factors that indicate that fatigue may be a factor in the safe operation of motor vehicles. For example, the failure of truck drivers to maintain proper lane position or to stay on the road were cited as a factor in 10 percent of the fatal crashes involving large trucks (FARS data, 1981). Such behavior could be an indication of driver fatigue. However, the behavior cannot with certainty be attributed to fatigue.

The BMCS hours-of-service regulation applies to drivers engaged in interstate and foreign commerce. Thirty-eight States have adopted such regulations or have a similar requirement. However, the present enforcement system has shortcomings: (1) both the BMCS and State agencies have limited manpower for an effective enforcement program, and (2) private and exempt carriers not engaged in interstate or foreign commerce generally remain outside the authority of BMCS and State enforcement agencies (Waller and Li, 1979).

BMCS has generally enforced its hours-of-service regulation through the use of driver log books. However, BMCS is seeking comments on a proposal to reduce the paperwork burden for motor carriers and drivers by permitting a less burdensome method of recording hours of service (Notice of Proposed Rulemaking by BMCS on February 22, 1982).

Among the alternatives being considered to monitor driver performance are a tachograph (an on-board mechanical recording device) and a modified motor carrier trip report. The tachograph records: when the motor started, how long it idled, when the vehicle started in motion, the speed at which it travelled, when and where the vehicle stopped, the distance between stops, and the total distance that was travelled. Driver trip reports are currently used by many carriers. With minor increases in the amount of detailed information required about on-duty driver activities (driving time, rest periods, meal breaks, where and when stops were made, etc.), these trip reports may be an acceptable substitute for the current driver logs, provided copies are retained by drivers for record purposes. However, enforcement would be complicated if the trip reports were not standardized among the carriers.

Alcohol Use

FMCSR prohibit the consumption of alcohol by a driver while on duty or within four hours of going on duty. Motor carriers are also responsible for not placing drivers on duty when they are known to have consumed alcohol within the preceding four hours.

The role of alcohol in vehicle accidents has been studied extensively and is well established for passenger car drivers. Almost one-third of all drivers involved in collisions resulting in one or more fatalities were found to be under the influence of alcohol (FARS data, 1981) as were one-fourth of all driver's involved in nonfatal injury producing collisions (Ferris et al., 1976; Terhune and Fell, 1981). The scope and nature of the drinking and driving problem among truck drivers are not so well defined, but some data are available.

Previous studies of truck accidents indicated that the following percentages involved the use of alcohol by truck drivers:

- 0.5 percent as reported by motor carriers (BMCS data, 1979);
- 2.0 percent for drivers of trucks over 26,000 pounds GVW in fatal accidents in 1976 (Cassidy, 1978);
- 1.0 percent for truck drivers reported by police in 1979 (Partyka, 1981); and
- 3 percent for truck drivers in 1978 (Najjar, 1981).

Generally, alcohol-related accidents among truck drivers ranged from less than 1 percent to 3 percent of total reported accidents, whereas in 1979 police-reported, alcohol-related accidents for passenger car drivers was 7 percent (Partyka, 1981). Any conclusions based on these differences must consider suspected underreporting of alcohol involvement, especially for truck drivers.

Among accidents in which the truck driver was fatally injured, alcohol involvement ranged from 36 percent (Baker, 1975) to 24 percent (Simpson et al., 1977). Accidents involving alcohol are identified in the FARS file by one of two methods--a chemical test or a statement by the investigating officer. Chemical tests for alcohol are primarily conducted on fatally injured drivers: about half the States have laws requiring such a test for all drivers killed in crashes. Only 57 percent of all drivers fatally injured during 1980 were tested for alcohol, and surviving drivers were tested only 19.1 percent of the time (FARS, 1980). Given the absence of detailed accident and exposure data, it is unknown whether or not any particular accident types are disproportionately represented for the alcohol-involved truck driver. Efforts are underway in NHTSA to improve reporting of alcohol use in both FARS and NASS.

Use of Other Drugs

BMCS safety regulations (Section 391, Physical Qualifications and Examinations) prohibit medical certification of a driver who uses amphetamines, narcotics, or any "habit-forming" drugs. Moreover, any driver in possession of, under the influence of, or using a narcotic, narcotic derivative, amphetamine, amphetamine derivative, or any other substance that would render the driver incapable of safely operating a motor vehicle may not operate or be in physical control of a BMCS-regulated truck.

Little is known about drug involvement in highway accidents. A study in Washington State (Crancer and McMurray, 1968) reviewed the driving records of 302 persons arrested for possession of illegal drugs and matched their records against the records of the State's other 687,228 drivers. The arrested group was divided into three subgroups: (1) those arrested for narcotics, (2) those arrested for dangerous drugs, and (3) those arrested for marijuana. Each subgroup had higher accident and traffic violation rates than the general driver population. This study contrasts with the Waller (1965) drug study of California automobile drivers that found an increase in violations but no difference in accident occurrence for drivers believed to have been under the influence of drugs. A more recent study of drivers injured in crashes (Terhune and Fell, 1981) indicated that 9.5 percent had THC (marijuana or hashish) and 7.5 percent had evidence of tranquilizers in their body. A very small percentage of the drivers studied were driving large trucks at the time of the crash (1.0 percent). None of these studies focused on drivers of large trucks. Until recently, there have been many methodological problems with drug analysis procedures used to detect and/or quantify drugs in a driver's blood or urine.

The Wyckoff (1979) interview data, about which methodological questions have been raised, showed that younger drivers (under 25) admitted using marijuana and amphetamines more often than did other age groups (Table IV-6). Wyckoff

TABLE IV-6

USE OF STIMULANTS AND DRUGS WHILE DRIVING
REPORTED BY REGULATORY STATUS AND AGE OF DRIVER (percent)

Use of Stimulants and Drugs	Regulatory Status				Driver's Age		
	Exempt	Private	Contract	Common	Under 25	25-50	Over 50
Use of Narcotics While Driving:							
Never	91.06	94.97	97.22	97.91	99.63	97.11	98.87
Once or twice	2.98	2.01	1.22	1.41	0.37	1.57	0.78
Occasionally	2.98	2.42	1.30	0.52	0.00	0.96	0.31
Regularly	2.98	0.60	0.26	0.16	0.00	0.36	0.04
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Use of Marijuana While Driving:							
Never	86.14	91.11	92.70	97.17	77.41	95.12	99.17
Once or twice	6.93	3.84	3.48	1.59	8.97	2.57	0.67
Occasionally	3.96	3.23	2.70	0.85	9.30	1.59	0.16
Regularly	2.97	1.82	1.12	0.38	4.32	0.72	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Use of Pep Pills While Driving:							
Never	48.26	68.89	74.61	86.55	61.28	71.71	90.08
Once or twice	11.94	10.51	10.47	10.60	13.80	11.31	4.64
Occasionally	29.35	18.18	13.87	2.65	20.20	15.40	5.00
Regularly	10.45	2.42	1.05	0.20	4.72	1.58	0.28
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Wyckoff (1979)

also claimed his data showed narcotics use was low for drivers of all ages, regardless of the regulatory status of their carrier-employers, and that use of "pep pills" was greater for all groups of drivers than was use of marijuana.

NHTSA plans a major study of alcohol and drug involvement in fatally injured drivers using the NASS data system in 1983. This study will include drivers of large trucks as a subpopulation and will provide needed data on the incidence of certain drugs in fatally injured truck drivers.

Driver Qualification

Qualifying drivers to operate large trucks is the joint concern of the Federal Government, the States, and the motor carrier industry. BMCS sets regulations for the qualification of drivers of large trucks engaged in interstate and foreign commerce. Qualification factors include age, driving record, experience, knowledge, and physical condition.

Most States use classified licensing systems to qualify drivers. They establish age limits (generally 18), may or may not give a road test in the vehicle to be operated commercially, and may perform some background checks before issuing a license to operate a vehicle. Adoption of special licensing procedures for drivers of large trucks has increased significantly since States began road-testing drivers in the type of vehicle they will drive. Thirty-one States have a classified license system and several others plan to implement such a system.

Motor carriers may impose additional or more stringent qualifications than are required by State or Federal standards. Company driver-qualification procedures normally include an application for license or employment, background and driver-record checks, medical certification, road tests, a written examination, and establishment of a driver file.

State agencies and motor carriers both are responsible for maintaining files on driver history, monitoring driver performance, and providing remedial actions or sanctions when required.

State licensing authorities routinely take action against drivers with excessive driving violations. They generally require an applicant to surrender all other State driver licenses held at the time a new license is issued. From information gathered through the National Driver Register (a compilation of the names of drivers whose operator privileges have been denied, withdrawn, suspended or revoked) and through communications with other State(s) from which the applicant reports holding a license, a licensing agency can often determine whether a driver's license should be issued to an applicant. However, drivers, particularly problem drivers, may not report to the State all of the required information (NHTSA, 1980).

Motor carriers are required by FMCSR (Section 391, Qualifications of Drivers) to investigate the background of each new driver within 30 days of employment. Such investigations include an inquiry into the preceeding three-year driving history from each State in which the applicant held an operator's license and from each previous employer. The investigation is usually based on information supplied by the driver in his application, which is supposed to include a list of all accidents, violations and employers for the preceeding three years, and a statement revealing any denial, revocation, or suspension actions against his drivers license. Once employed, the driver is required annually to provide the motor carrier with a list of convictions during the past 12 months for a yearly motor carrier review of his performance.

The States' driver history files usually contain only a record of convictions. Accident notations are not posted unless a conviction was sustained. Further, if the applicant deliberately fails to report that he held a license in a particular State, the driving record in that State will not be checked. In accordance with Federal guidelines, the Driver License Compact (Council of State Governments, 1961), and the Uniform Vehicle Code (NCUTLO, 1979), state licensing authorities must report convictions of non-residents to the driver's home State of licensure and to post and treat major offenses reported in other jurisdictions as if they had occurred in the home State. Even though the provisions of the "one license and one record concept" are endorsed by driver licensing authorities, adherence to the concept is hampered by inconsistent State laws, regulations, and operational practices (McBride and Jones, 1981). One study that compared previous convictions of accident-involved truck drivers reported that they had more speeding and other moving violation, and driving under the influence of alcohol charges, suspensions, and revocations than did passenger car drivers (Partyka, 1981).

No accurate assessment exists of the number of drivers who have multiple licenses or multiple driving records. In 1980, the National Transportation Safety Board (NTSB) conducted a nationwide investigation of 44 commercial drivers involved in large-truck accidents. From State driver records NTSB learned that these 44 operators held 63 driver's licenses, had 98 license suspensions, were involved in 104 traffic accidents, and had 456 traffic convictions. One of the conclusions of the investigation was that "loopholes at each level of the system for detection and control of problem commercial drivers . . . permit many problem drivers to escape detection and control, and obtain driver licenses and employment to operate large trucks, in spite of their records of unsafe driving" (NTSB, 1980).

In 1979 the American Association of Motor Vehicle Administrators surveyed interstate large-truck operators in six States and one Canadian Province. Results indicated that 10.8 to 32.1 percent of the 3,370 operators surveyed held driver licenses in more than one jurisdiction and the National Driver Register file revealed that 10 percent of them had had licenses suspended or revoked in at least one jurisdiction (AAMVA, 1981).

NHTSA is sponsoring two studies to define more fully the extent of the multiple licensing/multiple record problem (Reiss, 1982 and Hackman, 1981). A third NHTSA effort seeks to develop reliable tests and procedures for evaluating entry level knowledge and skill of applicants for large-truck driver licenses (Edwards, 1983).

Driver-Safety Motivation Programs

Motor carriers have used safety meetings to bring safety-related issues to the attention of their drivers. Some carriers have added fuel economy and training programs to management of driver-employees (Wiltshire, 1980). Most fuel-economy driving techniques are also safer driving techniques. For example, staying at or below the speed limit, previewing traffic far enough ahead to reduce the need for panic braking or road hazard avoidance maneuvers, maintaining adequate following distances, not only reduce fuel consumption but are inherently safe and help the driver remain alert.

One carrier (Galligan, 1981) who implemented such a program claimed to have increased fuel efficiency by 24 percent. The carrier also reported a 50 percent reduction in the accident rate--from 3.0 to 1.5 accidents per million vehicle miles. Companies can more easily measure a driver's fuel usage than his driving performance; fuel consumption data could therefore serve as a reasonable surrogate for driving performance data, and motivating drivers to use techniques to conserve fuel may result in an overall improvement in safety performance as well.

VEHICLE-RELATED CONTRIBUTING FACTORS

Vehicle design and maintenance are recognized as contributing to accident causation either directly (as in the case of a tire blowout) or indirectly (as when a vehicle with a low rollover threshold overturns during a severe maneuver). The extent to which vehicle factors interrelate with driver factors and highway or environmental characteristics to "cause" an accident is often difficult to establish.

Nevertheless, attempts have been made to estimate the role of vehicle components or performance properties as contributing factors in accidents involving large trucks. Studies indicate that vehicle component problems are detected in 5-13 percent of truck accidents and that the majority are partially attributable to brake or tire failures (BMCS, 1979 and Commonwealth of Kentucky, 1980). Smist and Ranney (1981) reviewed a limited number of accidents that involved large trucks and attributed 12.8 percent of them to vehicle factors alone. An additional 20.6 percent were associated with driver factors in combination with vehicle and highway or environmental deficiencies which possibly could have been avoided had the truck been "more forgiving."

NHTSA investigates safety-related defects in performance, construction, components and materials in motor vehicles and motor vehicle equipment. Confirmed defects are identified by NHTSA or the manufacturer and lead the owner to check and return the vehicle to a dealership for repair. Problems in tracking a vehicle through several owners and disregard of notices by owners results in a return rate of about 50 percent for all announced vehicle "recalls." The influence of manufacturer-related defects on large-truck accidents is difficult to quantify. However, between January 1, and November 15, 1981, there were 29 announced large-truck safety-related defect recalls covering 109,670 vehicles. These recall campaigns typically involved steering and braking systems.

This section describes the influence of large-truck size, configuration, and weight on accident frequency and severity and discusses specific issues of truck crashworthiness and crash-avoidance capabilities. It includes discussion on vehicle performance characteristics which, if improved, could result in accident avoidance by compensating for inherent driver limitations or lapses in driver skills.

Truck Size, Configuration, and Weight

Vehicle design characteristics related to size and configuration include truck length, width, number of towed units, cargo body type, and gross vehicle weight. The single-unit versus combination-truck accident experience was discussed in Section III (Truck Accident Experience) and will not be repeated in this section.

Truck size and weight covers a variety of issues: off-tracking, passing time, splash and spray, aerodynamics, backing, speed on grades, braking, and handling and stability. A report by the Western Highway Institute (1980) claimed that most of these factors were not adversely affected by increases in truck length, weight, and number of trailers. However, braking and handling and stability can deteriorate as truck length, weight, and the number of towed trailers increases. These latter issues are discussed elsewhere in this section.

-- Single- Versus Double-Trailer Combinations

Efforts to determine the relative accident involvement rates of single-trailer (singles) and double-trailer (doubles) combination trucks have resulted in a range of conflicting findings.

One of the earliest analyses of "singles versus doubles" was reported by the Federal Highway Administration (1969). Vehicle involvement rates were calculated using accident and mileage data for the years 1965-68 supplied by two interstate motor carriers operating double- and single-trailer combination trucks in western States. The results, as listed in Table IV-7, showed double-trailer combinations had lower accident rates. This was partially

TABLE IV-7

ACCIDENT RATES OF DOUBLE-TRAILER COMBINATIONS AND SINGLE-TRAILER COMBINATIONS OWNED BY TWO LARGE TRUCKING COMPANIES

	Consolidated Freightways*			Pacific Intermountain Express*		
Year	Vehicle involvements	Truck-miles operated (thousands)	Involvement rate per 100 million VMT	Vehicle involvements**	Truck-miles operated (thousands)	Involvement rate per 100 million VMT
1964	(a) 117	31,130	376	-	-	-
	(b) 470	89,504	525	-	-	-
1965	(a) 189	41,246	458	-	-	-
	(b) 517	107,315	482	-	-	-
1966	(a) 260	77,521	335	-	-	-
	(b) 468	96,391	486	-	-	-
1967	(a) 330	116,044	284	-	-	-
	(b) 449	77,762	577	-	-	-
1968	(a) 433	157,242	275	(a) 92	40,022	230
	(b) 415	71,462	581	(b) 91	19,731	461
Totals for period covered	(a)1,329	423,183	314	(a) 630	210,709	299
	(b)2,319	442,433	524	(b) 698	184,621	378

*(a) - Double-trailer combinations.
(b) - Single-trailer combinations.

**Totals only were furnished for the four-year period, 1965-1968. In addition, data for the last six months of 1968 were furnished separately.

Source: FHWA (1969)

attributed to more stringent standards in hiring drivers and closer supervision of these drivers, and not necessarily inherent to double-trailer combination characteristics.

In 1977, the BMCS examined accident and mileage data from seven carriers who operated both single- and double-trailer combinations. As shown in Table IV-8, the accident rates for single-trailer trucks were also consistently higher from 1969 to 1976, excepting 1975, than for double-trailer trucks. Other data that support the favorable safety record of double-trailer trucks are contained in Table IV-9 showing the results from two turnpike studies (Little, 1974 and Scott and O'Day, 1971). Both studies noted, however, that the lower accident rate for double-trailer combinations may be influenced by the fact that the turnpikes maintain strict controls on the operations of these trucks.

Using accident data from the second half of 1972, the California Highway Patrol (Zieszler, 1973) compared the accident rates of three classes of trucks, buses, and all other vehicles (Table IV-10). Miles of travel for each class of vehicle were estimated by applying estimated mileage to the number of vehicles registered in each class. Zieszler concluded that the rates of fatal and nonfatal injury producing accidents were the same for double-trailer trucks as for single-trailer trucks. Another study (Yoo et al., 1978) used 1974 California Highway Patrol accident and estimated travel data. Yoo et al. reported that:

- No significant difference was found between the number of double-trailer and single-trailer truck accidents or injuries per million vehicle miles of travel;

- Double-trailer truck accidents resulted in a significantly higher number of persons killed per million vehicle miles than singles; and

- Single-trailer combination trucks had a significantly higher accident frequency and injury rate per million cargo ton-miles of travel, but no difference was noted in the number of fatalities per million ton-miles.

TABLE IV-8

ACCIDENT RATES* FOR SINGLE- AND DOUBLE-TRAILER TRUCK COMBINATIONS FOR SEVEN CARRIERS

Year	Single-Trailer	Double-Trailer
1976	84.8	57.2
1975	70.7	73.3
1974	88.0	59.0
1973	94.0	76.1
1972	79.5	66.0
1971	76.8	64.0
1970	96.3	62.4
1969	84.5	52.9

*Accidents per 100 million vehicle miles of travel

Source: BMCS (1977)

TABLE IV-9

ACCIDENT RATES* FOR SINGLE- AND DOUBLE-TRAILER TRUCK COMBINATIONS ON TWO TURNPIKES

Location	Single-Trailer	Double-Trailer
Ohio Turnpike[1]	139	76
Indiana Turnpike[2]	172	84

*Accidents per 100 million vehicle miles of travel

Sources: [1]Little (1974)
[2]Scott and O'Day (1971)

TABLE IV-10

ACCIDENTS RATES* BY VEHICLE TYPE

Vehicle Type	
Double-Trailer Combination Truck	51.3
Single-Trailer Combination Truck	47.5
Other Trucks	71.8
Commercial Buses	37.5
All Other Motor Vehicles	70.7

*Accidents per 100 million vehicle miles of travel

Source: Zeiszler (1973)

Vallette et al. (1981) found that the accident involvement rates of double-trailer combinations greatly exceeded those of single-trailer combinations for all roadway types (Table IV-11). The largest difference was on rural nonfreeways where double-trailers experienced a rate more than 4.5 times that of single-trailer combinations. Although California's double-trailer mileage represented 30-35 percent of the total national mileage for double-trailer combination trucks, as this study notes, caution should be exercised in extrapolating these results to the Nation as a whole because of the high concentration of data from California and Nevada.

A recent study (Campbell and Carsten, 1981) found the fatal-accident rate of double-trailer trucks almost 50 percent higher than that of single-trailer combinations (Table IV-12) and the nonfatal-injury accident rate of double-trailer combinations over 2.5 times that of single-trailer combination rates (Table IV-13). This study also found that "bobtails" (tractor only) were overinvolved in accidents as compared to tractors with trailers.

Glennon (1979) studied 188,296 point-to-point 1978 trips by both single-trailer and double-trailer combinations of one interstate carrier. Total mileage travelled by each truck group was a little more than 56 million miles and the frequency of accidents was almost the same for the two groups: singles experienced 100 accidents and doubles experienced 106. These findings were contrary to the results of the latter two studies cited, except it was understood that the carrier whose 1978 operations were studied infrequently operated double-trailer combinations empty. Such a consideration may partly explain the apparent differences in the results of the last three studies because the Vallette study concluded that a major contributor to the higher accident rate for double-trailer combinations was the increased likelihood of collision at low gross vehicle weights.

-- Triple-Trailers, Turnpike Double-Trailers, and Other Combination Trucks

Triple-trailer combinations currently operate under special permits on selected highways in a limited number of western States. Peterson and Gull

TABLE IV-11

ACCIDENT RATES* BY TRUCK TYPE AND ROADWAY TYPE

Truck Type	Roadway Type: Rural Freeway	Rural Nonfreeway	Urban Freeway	Urban Nonfreeway
Single-Trailer Combination Truck	77	97	279	294
Double-Trailer Combination Truck	129	434	449	524
Single-Unit Trucks	43	111	84	171

*Accidents per 100 million vehicle miles of travel

Source: Vallette et al. (1981)

TABLE IV-12

FATAL-ACCIDENT INVOLVEMENT RATES* BY NUMBER OF TRAILERS: INTERCITY TRACTORS ONLY

Model Year	Single-Trailer Combination Truck		Double-Trailer Combination Truck	
	Rate	95% C.I.**	Rate	95% C.I.**
1974	5.9	±0.8	24.0	±4.4
1975 Pre***	12.5	±2.3	45.4	±7.6
1975 Post***	3.2	±0.6	4.8	±1.2
1975 Total	7.6	±1.0	15.0	±2.9
1976	7.6	±3.2	10.2	±3.6
1977	5.9	±0.2	2.8	+0.5
Total+	6.5	±0.6	9.5	±1.1

*Per 100 million vehicle miles of travel
**C.I. = Confidence Interval
***Pre- and post-standard vehicles (FMVS 121)
+Difference significant at .001 level

Source: Campbell and Carsten (1981)

TABLE IV-13

SUMMARY OF INVOLVEMENT RATES* FOR TRACTORS
BY EXPOSURE CATEGORY: INTERCITY USE ONLY, MODEL YEARS
1974-1977 COMBINED

Exposure Variable and Levels	Fatal (Calender Yrs. 76-78)		Injury (Calendar Yrs. 76-77)	
	Rate	95% C.I.**	Rate	95% C.I.**
Trailer Type				
Without Trailer	90.0	±44.5	913.5	±1032.3
With Trailer	6.8	± 0.7	53.5	± 18.3
Difference	83.2	±44.5	***860.0	±1032.7
Single-Trailer	6.5	± 0.6	47.9	± 11.9
Double-Trailer	9.5	± 1.1	126.3	± 25.7
Difference	-3.0	± 1.3	-78.4	± 28.3

*Per 100 million vehicle miles of travel
**C.I. = Confidence Interval
***Differences significant at 0.5 level except when marked with asterisk.

Source: Campbell and Carsten (1981)

(1975) evaluated their operation on an Interstate highway in Utah. Using mileage data from participating trucking companies and one year of State accident data, they determined that triple-trailer combinations had an accident rate of 2.09 accidents per million vehicle miles compared to a combined single- and double-trailer combination truck accident rate of 1.79 accidents per million vehicle miles. The higher rate for triple-trailer trucks was statistically insignificant, however, because the rates were based on small sample sizes--eight accidents for triple-trailers and 17 for the other combination groups.

The so-called "turnpike double" consists of a tractor and two forty-foot or forty-five foot trailers. This combination is currently allowed on some controlled-access highways. A study in Michigan (Engineering Standards Unit, 1976) concluded that the use of this combination type should not be allowed on non-controlled-access routes because of potential operational problems. Accident experience was documented between 1960 and 1976 for 100-foot double-trailer operations on the Ohio Turnpike. Thirty-six accidents, including one fatality, were recorded for 45,787,118 vehicle miles travelled. The resulting rate of 0.79 accidents per million vehicle miles was relatively low but it should be stressed that the sample was limited to operations stringently controlled and on a turnpike with relatively high safety standards. As with the triple-trailer combination trucks, it appears that under strict operating conditions "turnpike doubles" present no special safety problems.

-- Truck Width

Federal regulations and most State regulations limit truck width to 96 inches, but 102-inch vehicles are permitted by some States on certain highways. In the Vallette et al. (1981) study, an attempt was made to relate vehicle width to accident frequency. Because the accident file did not contain a reasonable sample of trucks with widths greater than 96 inches it was impossible to determine the effect of width on accident involvement.

-- Wide Loads

Glauz et al. (1974) investigated what other motorists did in the vicinity of mobile and modular housing shipments that might have safety implications. They concluded that reported accident rates and severities for accidents involving transport of mobile and modular homes were similar to those for other large trucks.

Another finding of the Glauz study was that overloaded tires--those carrying more than 2,500 pounds per tire--had 14 flat tires in 20 trips; when carrying less than 2,500 pounds per tire, there was only 1 flat tire in 20 trips. The importance of this finding is that a flat tire results in a wide load remaining stationary on the highway while the flat is being repaired--a situation assumed to present a serious hazard, especially on two-lane highways or roads with narrow shoulders.

The Florida Department of Transportation (1972) evaluated 12-foot-9-inch wide modules used in construction of hotels by observing a demonstration vehicle as it travelled city streets, two-lane and four-lane highways and across controlled multi-lane highways. The two observers who followed the vehicle noted problems of encroachment on adjacent lanes by the vehicle and delays caused to other motorists.

The California Highway Patrol (1981) compiled data on the transport of mobile homes and concluded that the running gear was overtaxed and likely to fail during shipment. More specifically, the tires, wheels, axles, brakes, and suspension were typically designed for a one-time shipment over a relatively short distance but were being recycled for continued use. A problem related to design overload and component fatigue was noted in approximately one of every seven transports. Average trip length was 142 miles.

-- Cargo Body Types

Because large-truck bodies generally are designed for the type of cargo to be carried, their shapes vary widely. The dynamic stability, post-crash consequences, and carrier operating practices are generally consistent for all trucks in a body-type category. For instance, bulk liquids and bulk solids are transported in cargo bodies that have a high center of gravity when loaded. This results in an increased tendency to overturn. Liquid "slosh" in unbaffled tank trucks aggrevate the rollover tendency.

Vallette et al. (1981) studied accident rates for trucks of different cargo configurations. Some were more often involved in accidents than others. As shown in Table IV-14, dump trucks had the highest rate among single-unit trucks and single-trailer combination trucks, and double-tankers were involved in accidents more often than other double-trailer combinations. National estimates of the number of accidents involving these two truck types were not available, but because dump trucks and tank trucks account for 8.8 and 9.8 percent, respectively, of total truck travel, they constitute a significant problem to safety (Burger et al., 1981).

Scott and O'Day (1971) also examined accident involvement by cargo-body type. The results (Table IV-15) showed dump trucks and transit mix trucks were overinvolved in accidents, based both on their percentage of the total vehicle population and miles travelled. The authors cautioned that their exposure values were based on census data and might not be a good estimate of actual exposure. In addition, differences in rates among the body types may reflect differing operational practices not accounted for in the study.

-- Truck Weight

Studies that have examined the relationship of vehicle weight to accident frequency and severity also have produced conflicting results. One of the earliest was a FHWA study (Winfrey et al., 1968) on the economics of the maximum limits of motor vehicle dimensions and weights. Accident data from three States collected during the late 1950s was matched with registered gross vehicle weights to determine accident involvement rates. The results (Table IV-16) showed that the heaviest weight group had the highest fatality rate but the lowest accident rate. Winfrey also found that the heaviest weight group consistently had the highest accident cost per mile of travel. Two serious limitations of this analysis were that it did not attempt to isolate vehicle weight from vehicle type, and that registered weights rather than actual weights were used.

TABLE IV-14

ACCIDENT RATES* BY CARGO AREA CONFIGURATION AND TRUCK TYPE

Cargo Area Configuration	Truck Type: Single-Unit	Single-Unit with Full Trailer	Single-Unit with Dolly	Combination Trucks: Single-Trailer	Combination Trucks: Double-Trailer
Fully Enclosed	38	57	145	101	198
Enclosed, Low Bed	**	**	**	59	192
Tank	122	76	**	197	767
Bulk Commodity	152	**	**	114	116
Pole/Log	**	**	413	19	**
Platform	52	49	148	100	286
Dump	221	48	165	330	298
Vehicle Carrier	**	**	470	188	**

*Accidents per 100 million vehicle miles of travel
**Rare or nonexistent configurations

Source: Vallette et al. (1981)

TABLE IV-15

RELATIVE INVOLVEMENT RATIOS FOR TYPES OF TRUCKS

Type of Truck	Relative Involvement Ratio: % Accidents / % Vehicles	Relative Involvement Ratio: % Accidents / % Miles
Van	0.84	0.70
Refrigeration Truck	1.20	0.99
Dump Truck	1.60	2.20
Tank Truck	0.77	0.83
Transit Mix Truck	1.20	3.30

Source: Scott and O'Day (1971)

TABLE IV-16

ACCIDENT RATES* BY REGISTERED GROSS WEIGHT OF TRUCKS

Registered Gross Weight (lbs.)	Fatal-Injury Accidents	Nonfatal-Injury Accidents	Property Damage Only Accidents	All Accidents
12,000 and Under	4.1	220	2050	2280
12,001-24,000	3.6	130	2000	2130
24,001-41,000	7.7	200	2750	2960
41,001-72,000	7.9	210	1440	1660

*Accidents per 100 million vehicle miles of travel

Source: Winfrey et al. (1968)

Using 1973 BMCS data, Herzog (1975) found that the fatality rate for "other than truck occupants" in truck-involved accidents increased as the weight of the truck increased. However, Hedlund (1977), analyzed 1973 and 1974 BMCS data and concluded that truck weight effects were small compared to the effects of rural versus residential/business areas and the number of roadway lanes. In rural areas weight appeared to have no effect. In residential/business areas there was a slight increase in fatalities as truck weight increased.

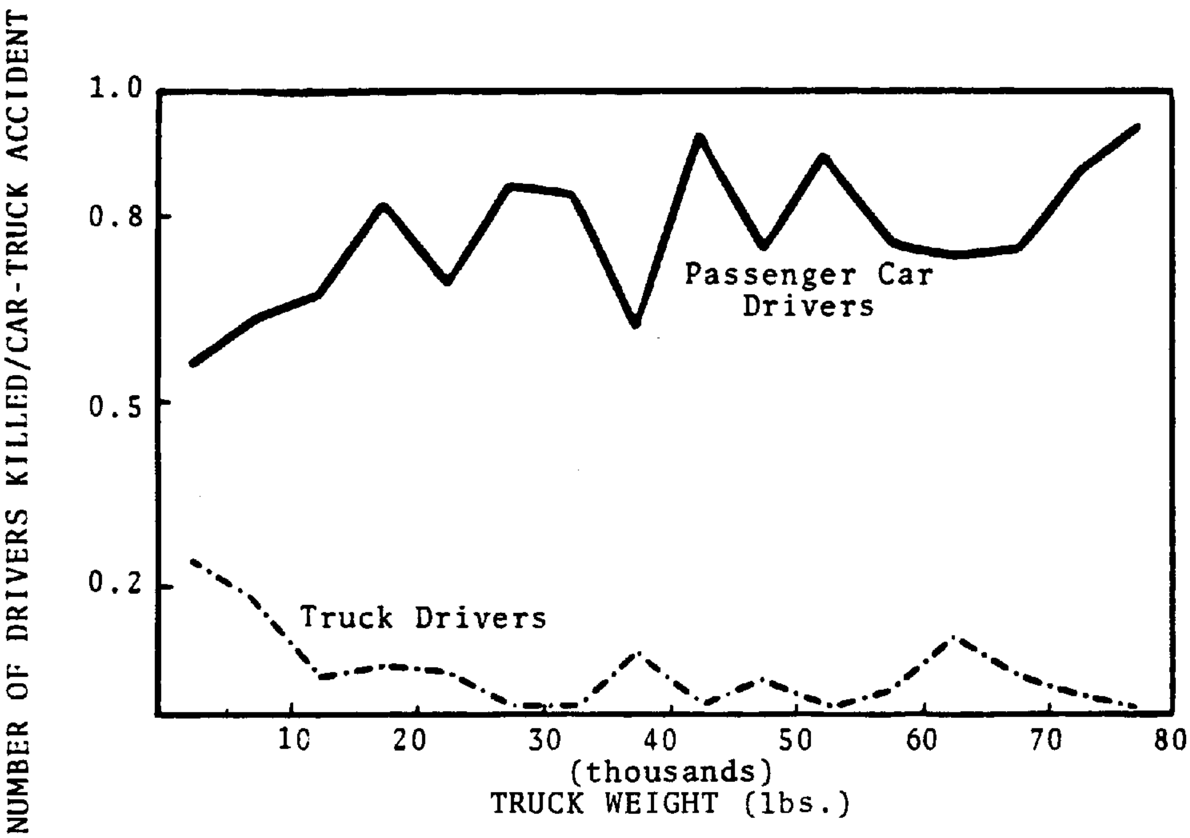
Another analysis of accidents by truck weight used 1973-75 BMCS data (Chatfield, 1976) and found that the highest number of fatalities per 100 truck accidents occurred in accidents involving trucks weighing from 70,000 to 85,000 pounds, but that trucks in essentially the same weight range, 75,000 to 90,000 pounds, accounted for the lowest number of persons injured per 100 accidents.

Belew et al. (1975) examined national fatal-accident files from January 1973 to June 1974 for the effect of truck weight on the fatality rate for both passenger car drivers and truck drivers (Figure IV-3). Although wide fluctuations were acknowledged, passenger car driver fatalities increased as truck weight increased. No consistent trend for truck driver fatalities was observed.

The Vallette et al. (1981) study also developed accident rates for various weights of two truck types--single-trailer and double-trailer combinations (Figure IV-4). The curves indicated that accident rates decreased with increasing truck weight. Concerned with the possible over-representation of loaded vehicles and under-representation of empty vehicles in the study, FHWA re-analysed the data and adjusted for this potential bias (included in Vallette et al., 1981). The results (Figure IV-5) indicate that accident rates for both single-trailer and double-trailer trucks decreased as truck weight increased. Doubles below 30,000 pounds had a significantly higher accident rate than did other doubles. Rates decreased with increasing weight up to 60,000 pounds, then increased moderately. Table IV-17 shows the data upon which the curves in Figures IV-4 and IV-5 are based.

FIGURE IV-3

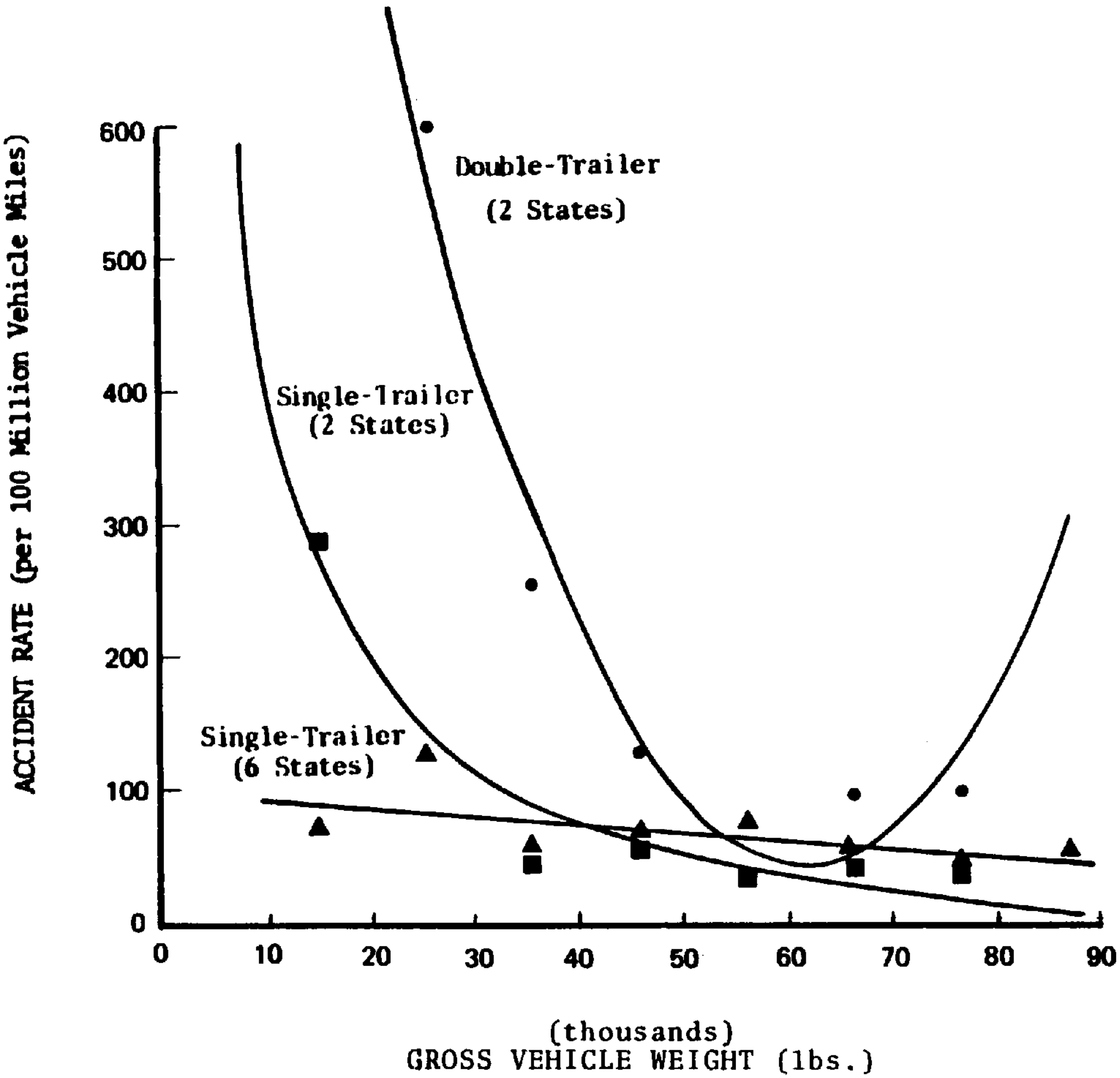
DRIVERS KILLED PER CAR-TRUCK ACCIDENTS
BY TRUCK WEIGHT



Source: Belew et al. (1975)

FIGURE IV-4

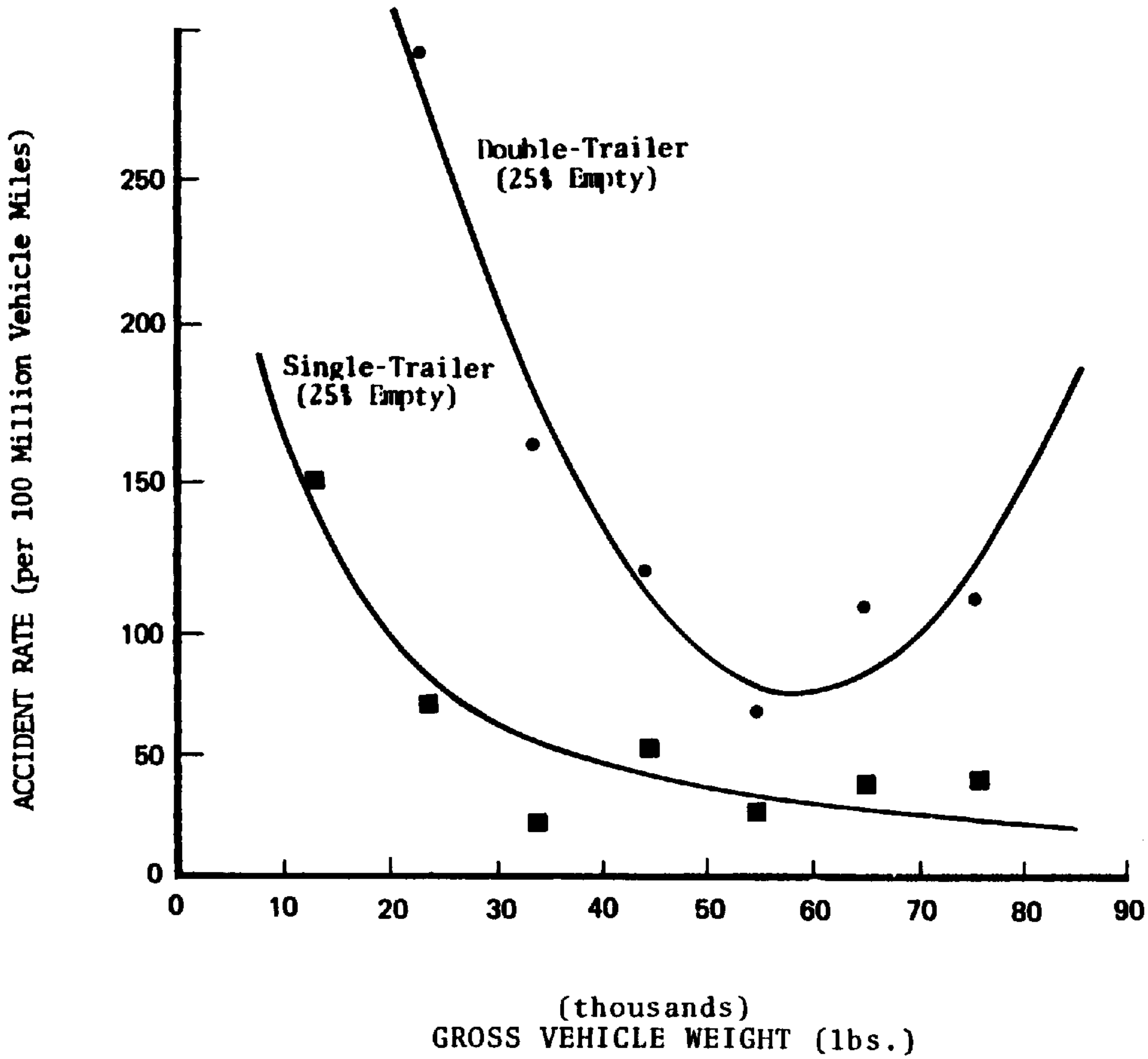
ACCIDENT RATES VERSUS GROSS VEHICLE WEIGHT



Source: Vallette et al. (1981)

FIGURE IV-5

ACCIDENT RATES VERSUS GROSS VEHICLE WEIGHT
FOR TWO STATES, CALIFORNIA AND NEVADA



Source: Vallette et al. (1981)

TABLE IV-17

ACCIDENT RATES* FOR SINGLE- AND DOUBLE-TRAILER COMBINATION TRUCKS BY WEIGHT CATEGORY (CALIFORNIA AND NEVADA COMBINED)

	Gross Vehicle Weight (lbs.) (thousands)							
	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90
Single-Trailer Combination Truck	291	136	49	61	37	44	45	-
Double-Trailer Combination Truck	-	606	260	134	68	101	103	26

*Accidents per 100 million vehicle miles of travel

Source: Vallette et al. (1981)

Apparently more important than gross vehicle weight is whether or not the truck is being driven empty of cargo. Vallette found that combination trucks exhibited a higher accident involvement rate while travelling empty than while operating with a partial or full load, and trucks towing empty double trailers were significantly more likely to be involved in an accident than trucks towing an empty single trailer. Vallette also found no relationship between accident severity and vehicle weight.

Large-Truck Crashworthiness

Until recently it was considered neither practical nor necessary to build many crash protection features into large trucks. This opinion gained acceptance, for the most part, because the mass of large trucks combined with the high speeds at which they often operate was thought to preclude practical efforts to mitigate the effects of the high energy levels produced by their crashes. Nevertheless, a significant number of truck occupant fatalities and serious injuries might be avoided with crash protection features such as collapsible steering columns.

A potential for reducing fatalities and injuries may also exist in making large trucks less "aggressive" when they strike or are struck by smaller vehicles. Efforts to develop underride guards to improve the survival potential of occupants of cars that impact the rear of large trucks illustrate that some practical technical solutions are possible.

This section discusses the nature of protection afforded occupants of large trucks when they are involved in accidents as well as the consequences to the occupants of nontrucks when involved in truck-related collisions.

-- Truck Occupants

In 1981 there were 1,131 fatalities to occupants of large trucks, according to FARS data. Of these fatalities, 815 (72 percent) were occupants of combination trucks, 292 (26 percent) were occupants of single-unit trucks, and 24 (2 percent) were "bobtail" occupants.

Although many fatal accidents involving single-unit and combination trucks were initiated when a truck struck another vehicle or a fixed object, the occupant deaths were most frequently attributed to subsequent rollover (Bondy and Partyka, 1980).

Rollover accounts for half of all fatalities in single-unit truck collisions even though single-units are less likely to overturn in a fatality-causing accident than are combination trucks. In contrast, only 26 percent of passenger cars in which an occupant was killed overturned (Partyka, 1979).

The truck occupant most frequently killed was a truck driver (72 percent for single-units, and 82 percent for both combinations and "bobtails"). Other combination-truck occupants killed in accidents were in the right-front passenger position (10 percent) and in the sleeper section of the cab (5 percent). Other occupants killed in single-unit trucks included right-front passengers (14 percent) and people riding on the vehicle exterior (5 percent). Only one occupant of a single-unit truck was killed in a sleeper section.

Partyka (1979) found that ejection from the cab was frequently associated with truck-occupant fatalities: 40 percent for single-units, 34 percent for combinations, and 41 percent for "bobtails." In contrast, 24 percent of passenger car fatalities were associated with ejection. About 97 percent of all fatally injured occupants were not wearing safety belts. The rate of safety belt use was the same for truck and automobile occupants killed in accidents (FARS data, 1980). In a study of injury producing accidents involving large trucks and other vehicles in 1978, 10.9 percent of the truck occupants and 13.8 percent of the occupants of the other vehicles claimed they were using safety belts (Najjar, 1981). NASS data for 1979-1980 indicate that 10 percent of all accident-involved passenger car occupants were wearing restraints. The difference in safety belt use between truck occupants involved in fatal accidents and those involved in nonfatal injury-causing accidents suggest that, similar to the protection afforded passenger car occupants, safety belt use reduces the likelihood that truck occupants will be seriously injured.

Discomfort caused by safety belt system designs and the jarring motion of the truck cab and seat are said to be disincentives to the use of safety belts in large trucks (NHTSA, 1979).

Truck crashworthiness inquiries must also address the relative levels of occupant protection afforded by different types of tractor cabs. Cab-over-engine tractors are often favored over cab-behind-engine types because they enable longer trailer-lengths within overall length regulations.

A few studies have examined the relative safety of the two types of tractors. In a study of California truck accidents, Philipson et al. (1978) found that a high ratio of accidents involving cab-over-engine tractors resulted in major injury or fatality.

A similar finding was reported by Campbell and Carsten (1981), who compared the relative safety of the two cab styles for truck model years from 1974 through 1977. Cab-over-engine tractors had a 70 percent higher involvement in fatal accidents. When only truck-driver fatalities were considered, the rate for cab-over-engine tractors was more than double the rate for cab-behind-engine tractors.

Data analysis by Kubacki and O'Day (1981) indicated a slightly higher fatality rate and a higher ratio of truck-driver fatalities or injuries per accident for cab-over-engine types (see Tables IV-18 and IV-19), but the authors cautioned that their conclusions were tentative because of potential inaccuracies in the accident and exposure data. If such a difference does exist in serious accidents involving the two cab-types, the authors said, it may be because of differences in operating environments and speeds. Cab-over-engine tractors were noted to be more likely found on long-haul trips and corresponding higher-speed operations than cab-behind-engine tractors. Conversely, the difference in injury and fatality rates could be related to tractor design: ejection of occupants appeared to occur more often in crashes of trucks with the cab-over-engine configuration.

TABLE IV-18

ACCIDENT, INJURY, FATALITY, AND EXPOSURE COUNTS
FARS AND TIU FOR MODEL YEARS 1974-77 COMBINATION TRUCKS
NON-LOCAL, ALL CARRIERS

Item	Cab-Behind-Engine	Cab-Over-Engine
Fatal Involvements	503	845
Driver Fatalities	64	140
Registered Vehicles	80,138	96,344
Vehicle Miles Travelled*	5.86	8.96
Fatal Involvement Rate**	85.8	94.3
Driver Fatality Rate**	10.9	15.6

*100 million vehicle miles travelled
**Per 100 million vehicles miles of travel

Source: Kubacki and O'Day (1981)

TABLE IV-19

ACCIDENT, INJURY, FATALITY, AND EXPOSURE COUNTS
BMCS AND TIU FOR AUTHORIZED CARRIERS, NON-LOCAL,
COMBINATION TRUCKS

Item	Cab-Behind-Engine	Cab-Over-Engine
Involvements	3325	4305
Driver Injuries	924	1385
Driver Fatalities	48	85
Registered Vehicles	82,348	122,910
Vehicle Miles Travelled*	58.3	101.2
Involvement Rate**	57.1	42.6
Driver Injury Rate**	15.9	13.7
Driver Fatality Rate**	0.82	0.84

*100 million vehicle miles travelled
**Per 100 million vehicles miles of travel

Source: Kubacki and O'Day (1981)

-- Occupants of Other Vehicles

1979-1980 FARS data indicate that 69 percent (4,344) of all the fatalities resulting from large-truck crashes occurred to occupants of other motor vehicles which either struck or were struck by a large truck. Almost three-fourths of these fatalities were passenger car occupants (3,097) and 86 percent of these (2,655) died in two-vehicle accidents as opposed to accidents involving three or more vehicles. NASS data (1979-1980) indicate that in about 67 percent of all car/large-truck accidents, the truck is the striking vehicle.

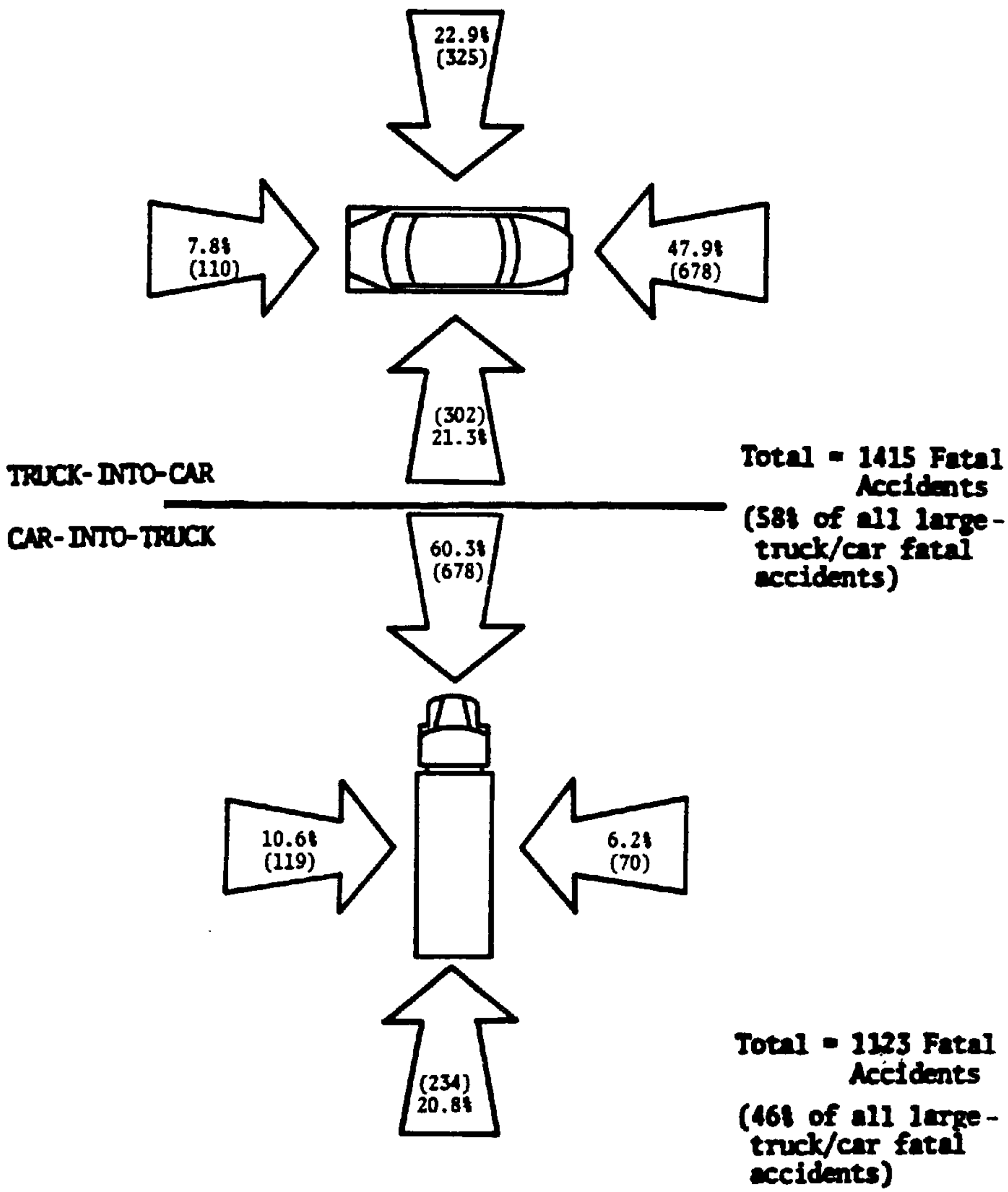
Figure IV-6 shows the initial point of impact on the struck vehicle in fatal large-truck/car accidents in which the striking vehicle impacted head-on. Of the total 1,860 fatal accidents that involved a frontal impact by one or both vehicles, 678 were head-to-head collisons. Cars struck the rear of large trucks as the initial impact point in 234 fatal accidents.

The Kubacki and O'Day (1981) study cited earlier showed that cab-type also influences the injury outcome to occupants of other vehicles involved in an accident with a large truck. While cab-over-engine types were found to be more often associated with truck-occupant injuries, collisions with cab-behind-engine combination trucks exhibited a somewhat higher incidence of injury to occupants of other vehicles. Conversely, Vallette et al. (1981) found that cab-type does not affect the severity of injury to occupants of other vehicles.

Passenger car collisions with the rear of large trucks are often spectacular because of the frequently fatal consequences to car occupants when their vehicle underrides the truck. Vehicles underride the rear or side of trucks in 5-10 percent of all accidents involving large trucks. Minahan and O'Day (1977) found that 90 percent of the fatal car-into-truck rear-end collisions

FIGURE IV-6

FATAL LARGE TRUCK/CAR ACCIDENTS INVOLVING THE FRONT END OF THE VEHICLE AS THE INITIAL POINT OF IMPACT (TWO-VEHICLE FATAL ACCIDENTS ONLY)



Source: Partyka (1981)

involved underride. Approximately 1.4 percent of all traffic fatalities occurred in rear-end accidents involving large trucks. Almost one-and-one-half times as many fatalities occurred as a consequence of passenger car impacts with large trucks than non-passenger car impacts (FARS data, 1981).

Federal regulations require that trucks and tractor-trailers in interstate commerce provide protection against rear underride, but clearance between the bottom of the underride protection device and the ground can be as much as 30 inches, which is higher than the bumper system and engine block of most automobiles. Testing of prototype underride guards by DeLeys and Ryder (1971) showed that energy attenuating systems were more effective than rigid devices. Zaremba et al. (1977) and Moffatt et al. (1980) also reported favorable results from crash tests of two guards designed to be more energy-attenuating. The guards were tested with a 21-inch ground clearance. They prevented occupant compartment intrusion of both small and standard-size automobiles at impact speeds of more than 30 mph.

BMCS and NHTSA are studying improved underride guard protection. The Texas Transportation Institute and Dynamic Science, Inc., have performed a series of DOT-sponsored crash tests. NHTSA used data from these tests to propose a rule (Notice of Proposed Rulemaking by NHTSA on January 8, 1981) which would require a guard to have moderate strength (approximately 45,000 pounds) and a 21.65-inch ground clearance. NHTSA is continuing to sponsor crash tests to obtain additional data on the effectiveness of the proposed requirement.

Large-Truck Dynamics and Crash Avoidance

Some accidents occur when a driver unknowingly exceeds the safe dynamic performance bounds of his vehicle. This may be especially true in combination and single-unit trucks where special driving skills are essential to safe operation.

Opportunities exist for improving large-truck performance. This subsection discusses large-truck brake systems (including maintenance), retarders, handling and stability, and tires and their role in collision-avoidance maneuvers.

-- Truck Brake-System Design

Large trucks are typically equipped with either drum or disc air brakes. The braking performance of vehicles equipped with air brakes is regulated by Federal Motor Vehicle Safety Standard (FMVSS) No. 121 which became effective in 1975. Reduction in loss of control due to wheel lockup was one of the major objectives of this standard.

The effectiveness of FMVSS No. 121 was evaluated by the Highway Safety Research Institute (Campbell and Carsten, 1981) when they examined model years 1974-77 which included both pre- and post-FMVSS 121 trucks. The authors concluded that the results showed no evidence of a substantial safety benefit from the standard. NHTSA also examined the data used in the Campbell and Carsten study. Truck travel data from the TIU (1977) were substituted and the results (Cooke, NHTSA, in a report to be released in 1982) indicate that reductions did occur in fatal-accident involvement for post-FMVSS 121 trucks when compared to the pre-FMVSS 121 trucks but these reductions were attributed, at least in part, to the effects of the differences in the ages of the trucks.

The brake system of a large truck is critical to its safe operation. Design and development of truck-braking systems that can operate optimally is complicated by the wide variation between empty and fully-loaded conditions of travel, by the usually high ratio between the height of the center of gravity and the vehicle's wheelbase, and by the articulation of combination trucks.

The comparatively longer stopping distance required by trucks can contribute to an accident. In 1974 BMCS tested the stopping distance performance of 366 cars and 1,200 trucks, both loaded and unloaded, at initial speeds of 20 mph. The average stopping distance for the passenger cars was 22.4 feet. Figure IV-7 summarizes the weight and braking distance results of commercial truck configurations. The average stopping distance for large trucks ranged from 32.7 feet to 43.8 feet--46 and 96 percent greater than cars, respectively. No restrictions were imposed on the number of wheels permitted to lock. Winter (1975) noted that earlier testing had shown that truck-stopping distances could be reduced 9 percent simply by adjusting the brakes.

Current production passenger cars are capable of panic stopping from 60 mph in less than 200 feet. When compared to trucks, a disparity is evident in the braking capabilities of the two types of vehicles. In tests of truck-stopping distances one wheel per axle was permitted to lock (Radlinski, 1976 and 1982). The results showed that a loaded 80,000-pound combination truck required 250 to 300 feet to stop from 60 mph. Unloaded, this same combination truck required 350 to 400 feet to stop from 60 mph. A "bobtail" or empty single-unit truck can require 300 to 500 feet. When distances between vehicles in traffic are short, these differences in stopping distances become decisive.

Trucks can lose directional stability when a wheel "locks" at any of their axles. Figure IV-8 illustrates this type of control problem for single-unit and combination trucks.

In single-unit trucks, directional control can be lost during braking in two ways: when the front wheels lock and do not rotate because of excessive brake torque, the vehicle becomes unresponsive to steering and continues straight ahead; when the rear wheels lock, directional stability is lost and the vehicle tends to "spin out," the rear-end swinging rapidly forward. Both conditions can be attributed to a property of pneumatic tires by which they require rolling motion to maintain directional stability. Otherwise, front tires do not respond to steering and rear tires are unable to correct the errant direction of the vehicle.

FIGURE IV-7

SUMMARY OF WEIGHT AND BRAKING DISTANCE OBSERVATIONS BY VEHICLE TYPE FROM INITIAL SPEEDS OF 20 MPH

VEHICLE TYPE	WEIGHT RANGE 1000's OF #	NUMBER TESTED	BRAKING DISTANCE RANGE (FT)
2-AXLE ≤ 10,000 LBS	4.3-10.0 (Av=8.3)	132*	18.5 – Av=25.6 – 49.5
2-AXLE > 10,000 LBS	10.0-39.0 (Av=16.0)	279	21.0 – Av=32.7 – 64.3
3-AXLE	14.3-63.4 (Av=31.6)	45	25.7 – Av=39.3 – 57.8
2-S1	10.7-44.3 (Av=27.1)	62	23.3 – Av=35.8 – 49.0
2-S2	19.3-63.9 (Av=32.5)	146	20.7 – Av=36.4 – 80.0
3-S2	21.5-78.4 (Av=44.3)	427	25.9 – Av=38.4 – 75.3
2-S3, 3-S1	19.9-71.8 (Av=32.3)	9	27.4 – Av=37.0 – 46.7
2-1, 2-2, 2-3, & 3-2	15.4-79.3 (Av=34.8)	29	30.6 – Av=42.5 – 60.8
3-S3, 3-S4, 3-S5, 3-S7, & 3-S8	29.9-137.1 (Av=76.4)	20	28.5 – Av=40.3 – 54.9
TWIN TRAILER COMBINATIONS	23.3-186.4 (Av=67.8)	51**	30.3 – Av=43.8 – 83.1

* - INCLUDES 98 2-AXLE VEHICLES FOR WHICH GROSS WEIGHT IS NOT AVAILABLE.

** - INCLUDES 3 SPECIAL PERMIT VEHICLES IN MICHIGAN WHICH EXCEEDED THE 136,000 LB GROSS WEIGHT LIMIT FOR 11-AXLE COMBINATIONS.

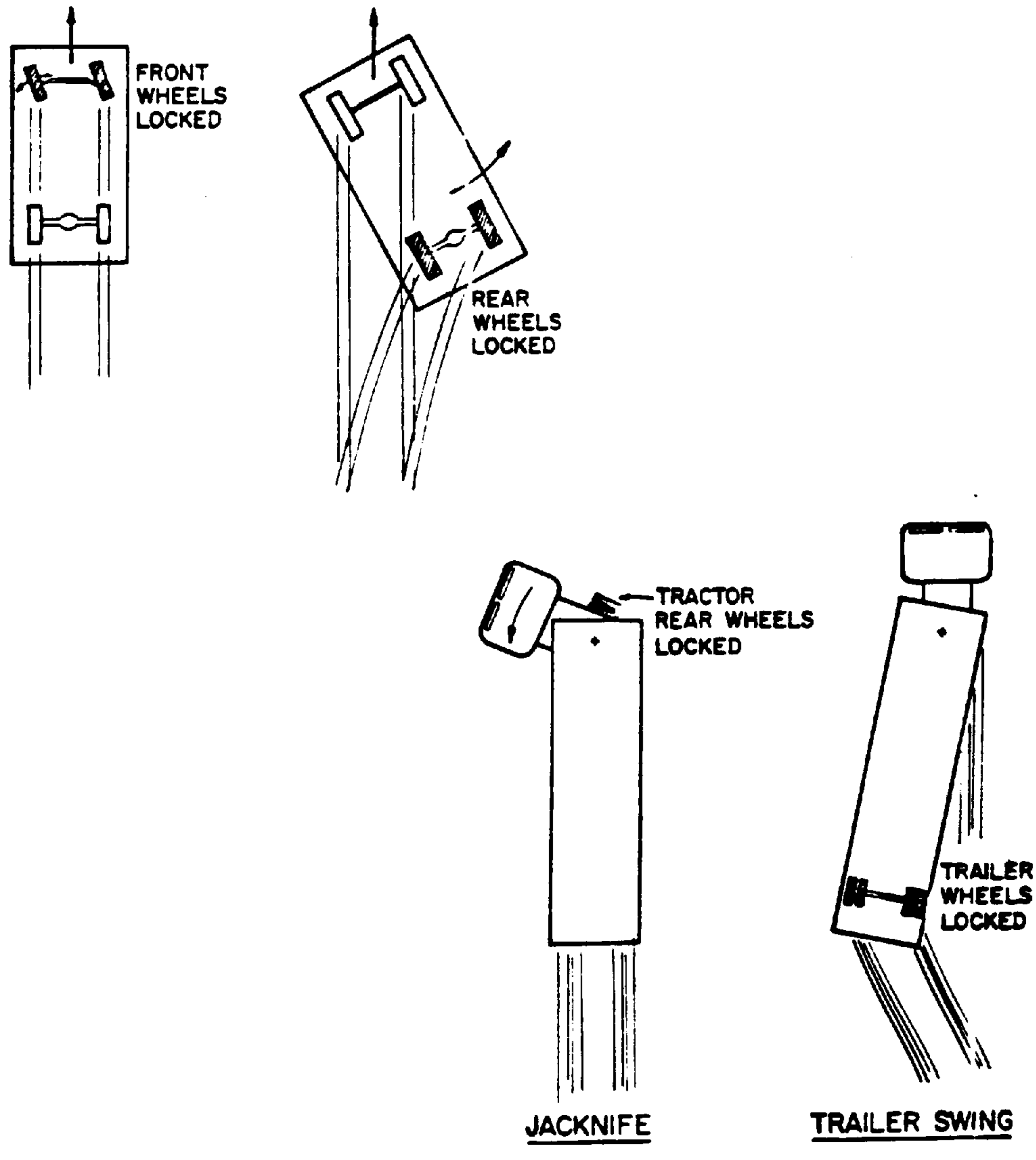
▼ - DENOTES AVERAGE

Source: Winter (1975)

FIGURE IV-8

LOSS-OF-CONTROL RESPONSES

OF SINGLE-UNIT AND COMBINATION TRUCKS



Source: Ervin (1980)

Two types of instability occur from wheel lockup in a combination truck. When the rear wheels of the tractor lock, a "jackknife" occurs similar to the "spin out" of single-unit trucks. The instability results in rapid rotation, requiring about one second for the tractor to rotate 120 degrees, at which point the cab strikes the body of the trailer. A second type of instability, called "trailer swing," occurs when trailer wheels lock. The trailer rotates relatively slowly, often without being noticed by the driver, because no immediately noticeable disturbance occurs to the tractor's motion.

Loss of control is common in single-vehicle large-truck accidents. In many cases braking instability is an accident-initiating or contributing factor. BMCS (1979) data for single-vehicle accidents indicate that run-off-road, "jackknife," and rollover accidents accounted for 23.2 percent of all reported truck accidents and 15.7 percent of truck-occupant fatalities. Bondy and Partyka (1980) found that 69 percent of all combination-truck occupant fatalities reported in FARS in 1979 occurred in single-vehicle accidents. A significant number of these may have been associated with loss of control.

When loaded to their maximum gross vehicle weight, large trucks have less reserve stopping capability than smaller vehicles. Heavier trucks in particular can experience heat buildup and subsequent brake "fade." The problem of "fade" is complicated by the introduction in recent years of more fuel-efficient engine designs. These engines provide less non-braking downhill retardation than did previous designs.

It is estimated that 25 to 50 drivers of large trucks are killed each year in "runaway" accidents (Fancher et al., 1981). A greater number of nonfatal "runaway" accidents was also estimated to occur. In many cases truck "runaway" is the result of poor brake maintenance or poor brake adjustment which causes braking demands, normally distributed to by the brakes on all axles of the vehicle, to be transferred to fewer axles. This increases the chances of heat buildup and "fade" on the axles that are required to absorb the braking demands.

"Retarders" are used on large trucks to assist the primary braking system by slowing the engine or drive line. They help eliminate or reduce heat buildup in the primary brake system, thus "saving" brakes for accident avoidance and stopping maneuvers. The use of these devices, while popular in some regions of the country and on some types of vehicles, is not widespread.

-- Brake System Maintenance

Truck brakes require more attention and maintenance than passenger car brakes. Several components in the brake systems of trucks are prone to wear and failure, requiring frequent repair or adjustment. BMCS annually spot-inspects large trucks as part of its overall safety program. In 1979 it spot-inspected 23,838 large trucks (BMCS, 1980). Forty-one percent (9,671) of those vehicles were removed from service for one or more defects sufficiently hazardous to make the vehicle's continued operation unsafe. The largest number of defects was found in braking systems (50.8 percent). In 1976 and 1977, 53.8 percent of the defects found were related to brake systems (BMCS, 1978). BMCS inspections dating back more than ten years reflect this same proportion, and findings of State inspecting agencies confirm those of Federal inspectors. For example, between June 1980 and January 1981 Oregon conducted weight and safety inspections of 2,556 large trucks and removed 48.9 percent of them from service, the majority for brake system defects. BMCS (1979) studied its accident data for 1976 through 1978 and found 4,291 accidents (4.8 percent of the total reported for those years) in which mechanical defects were reported to have been contributing factors. Brake system failures were the single largest group cited, contributing to 31 percent of all accidents related to mechanical defects. In a review of its 1978 and 1979 accident data, the Commonwealth of Kentucky (1980) found that brake system problems contributed to 5 percent of all combination-truck accidents.

Lohman and Waller (1975) reported that vehicle defects were found in 8 percent of the large trucks and 10.8 percent of single-unit trucks weighing more than 24,000 pounds that were involved in truck accidents in North Carolina. Zieszler's (1973) analysis of truck accidents in California showed that combination trucks had a slightly lower incidence of defective equipment (6.2 percent) than did single-unit trucks (7.4 percent). Finally, Vallette et al. (1981) reported that defective truck equipment was more often found involved in single-vehicle accidents (24 percent) than in multiple-vehicle accidents (11 percent).

McDole and O'Day (1975) found that vehicle defects were a contributing factor in more than 6 percent of the truck accidents reported to police agencies in Texas, compared to 2 percent of the passenger car accidents reported. Truck defects were cited as a "cause" in about 10 percent of the accidents when the trucks involved were at least 10 years old, but in only 4 percent of the accidents when the trucks were less than 3 years old. The defects most often reported were in brake, tire, and wheel systems--accounting for about 70 percent of all defect-related accidents.

McDole and O'Day (1975) also concluded that a relationship existed between good inspection and maintenance practices and lower rates of defect-related accidents. They found that more effective maintenance practices were usually adopted by larger firms, which considered such maintenance to be of economic benefit. Poorer maintenance practices were more likely to be associated with smaller firms (1- to 5-vehicle fleets) or individual owners who did not commit the resources necessary for adequate maintenance and inspection. Only 16 percent of the small fleets surveyed required written pre-trip inspection reports, whereas 59 percent of the large fleets required of them.

The most important "detection mechanism" for identifying defects was considered by McDole and O'Day (1975) to be the driver himself. They identified the major accident-causing defects as those which are visually detectable--defective tires, brakes, lights, and wheels. The report emphasized the importance of pre- and post-trip inspections by drivers.

Drivers of carriers regulated by BMCS are required to "satisfy themselves" that the various truck components are in safe working condition before each trip and to complete a vehicle inspection report after each trip.

A three-year BMCS demonstration program is attempting to evaluate whether a Federally financed effort to encourage States to expand their vehicle weighing and inspection schedules would increase truck safety. Utah, Idaho, Alaska and Michigan are cooperating in the program. As of August 1981, three out of the four States inspected and weighed more vehicles than they had before the demonstration program started. Commercial vehicle accidents decreased 37 percent in Idaho and 43 percent in Utah after the project began. Data were not available for the other two States.

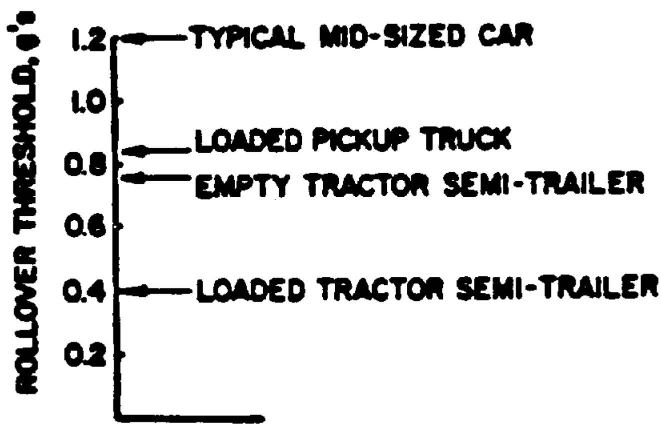
-- Handling and Stability

In addition to the dynamic instability that can occur in large trucks as a result of simple braking actions, instability can also result from steering maneuvers which, if made at certain speeds, can cause unstable lateral motions or a rollover.

Large trucks, especially some combination trucks, are susceptible to rollover, "spin out" and "jackknife" even in routine turning maneuvers (Figure IV-9). For example, the tractor of a combination truck may "spin out" on curves even without braking. Typical passenger cars can successfully execute cornering maneuvers on dry pavement that require up to 0.8 - 0.9 g's of lateral acceleration. By comparison, many fully-loaded large trucks become unstable

FIGURE IV-9

STATIC ROLLOVER THRESHOLDS FOR
VARIOUS VEHICLES



Source: Ervin (1980)

during cornering at 0.3 - 0.4 g's of lateral acceleration. The stiff rear springs often found on large trucks and the high center of gravity typical of loaded trucks combine to create a condition which, when coupled with other, often subtle factors, can cause the rear tires to lose stability. As the sharpness and speed of the turn increase, the vehicle becomes increasingly less stable.

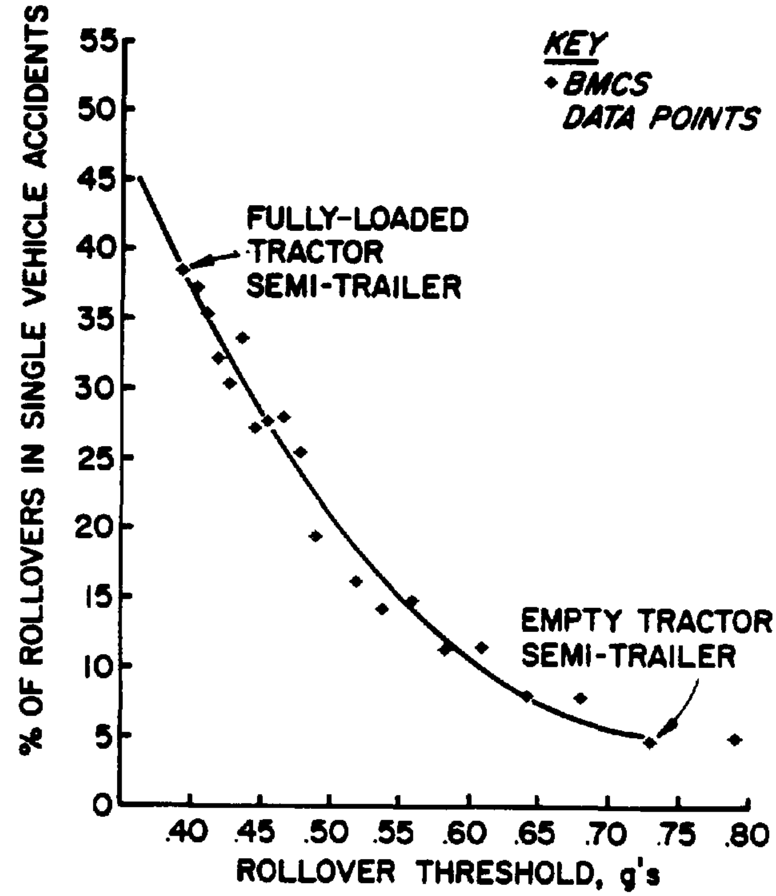
When combination trucks change lanes rapidly, sideways movement of the last unit in the combination tends to be greater than that of the tractor, creating a whip-like effect. The movement is even more exaggerated if the last trailer is loaded more heavily than those ahead of it. Trailers typically used in double-trailer combinations may experience as much as twice the lateral accelerations as those experienced by the tractor and may overturn as a result.

Single-vehicle accidents, including those that involve pedestrians or bicyclists, are generally thought to be those in which handling and instability tendencies are most likely to be contributing factors. BMCS (1977) reported 13.4 percent of all truck accidents and 51.6 percent of all single-vehicle truck accidents involved to either rollover or jackknifing. NASS data (Partyka, 1981) indicated 49.8 percent of the accident-involved large trucks overturned and 19.6 percent "jackknifed."

A review of 1976-78 BMCS accident data by Ervin et al. (1980) found a close relationship between rollover threshold and the number of accidents involving rollover. The sampling in Figure IV-10 represents 21,000 single-vehicle accidents that involved three-axle tractors pulling two-axle van-type semi-trailers.

FIGURE IV-10

PERCENT OF SINGLE-VEHICLE ACCIDENTS IN WHICH ROLLOVER OCCURS AS A FUNCTION OF THE VEHICLE'S INHERENT ROLLOVER THRESHOLDS IN G'S



Source: Ervin et al. (1980)

Rollover and "jackknife" accidents were comparatively high-risk accidents for occupants of large trucks. Bondy and Partyka (1980) found that 56.2 percent of the fatalities to occupants of combination trucks occurred in rollover accidents and 55.6 percent of injured occupants of combination-truck occupants were involved in "jackknife" accidents.

-- Truck Tires

Two characteristics of truck tires that present potential safety hazards unique to large trucks are traction and blowout potential. Truck tires possess about 20-30 percent less longitudinal and lateral traction properties than do passenger car tires (Boyd et al., 1979). This reduces both the stopping distance and lateral stability of the truck because the governing factor is the amount of friction that can be achieved between the tire and the roadway.

Because of the heavy loads carried under conditions of underinflation and overheating, truck tires are more prone to blow out or catch fire than are car tires. If a blowout occurs, particularly on the steering axle, it can cause loss of control and an accident.

Contact with road obstructions or severe pavement irregularities, excessive loading of the tire, and excessive wear are the leading causes of tire blowouts. Anderson et al. (1975) reported that tire failure accounted for less than 1 percent of the total accidents reported to BMCS, and for 4-5 percent of the large-truck accidents that occurred on the Ohio, Indiana, and Pennsylvania Turnpikes from 1966 through 1972.

<u>Aerodynamic Disturbance and Splash/Spray Effects</u>

Two potentially adverse effects of large trucks on other vehicles are aerodynamic disturbances caused by the airflow around the truck and the splash or spray from wet pavement.

The nature and magnitude of the effect of truck-induced aerodynamic disturbances on passenger cars were investigated in a series of laboratory and test-track experiments (Weir et al., 1971). The measure of safety performance was the peak lateral displacement of a car's path from the lane centerline during the airflow disturbance. Results showed that when a car passed a truck, the truck's wake caused the passenger car to displace laterally from 0.5 feet to 3.3 feet, depending upon lane width, relative and absolute speeds, initial vehicle clearances, and crosswind conditions. During the tests the automobile driver did not attempt to steer against the displacements. In a real-world situation, a driver may be able to compensate for such disturbance by corrective steering.

Large trucks operating on wet roads create a spray cloud of water vapor, usually dirty. This spray is a potential hazard to the truck itself and to other motorists on the highway. By obscuring the truck driver's rear vision, it can increase the possibility of lane-change accidents with unseen vehicles alongside the truck. Also, stress in attempts to use spray-fouled mirrors adds to the truck driver's otherwise difficult task of operating the vehicle in adverse weather. The spray simply obscures the vision of motorists who attempt to pass in the rain and can increase the likelihood of an accident.

Effective devices to suppress truck splash and spray, such as tire flaps and side panels, are commercially available.

Truck-Generated Stress: Heat, Noise, and Vibration

Drivers of large trucks are subjected to varying degrees of heat, noise, and vibration with potentially negative physiological or psychological effects which can increase the likelihood of accidents as a result of stress-induced fatigue. Experimental research (Mackie et al., 1974) indicated that truck cab-heat decreased alertness and increased fatigue. Also, drivers suffered some temporary loss of hearing at high cab-noise levels and some of the cab-vibration conditions were considered borderline with respect to International Standards Organization fatigue-induced proficiency standards.

Neither heat nor noise in truck cabs appear to be a significant problem. Cab air-conditioning was the obvious countermeasure for excessive heat. The International Brotherhood of Teamsters made cab air-conditioning a requirement in the 1977 National Master Freight Agreement. Likewise, the promulgation and enforcement of BMCS in-cab noise emission standards, coupled with the Environmental Protection Agency's maximum allowable exterior noise level standard--83 decibels in 1978--for large trucks as manufactured, has significantly reduced noise levels in truck cabs. For example, BMCS measured the cab-noise levels of 39,000 large trucks. In 1976, the number of trucks at or above the 90 decibels allowed was 7.4 percent of those examined. By early 1981 this had declined to 2.3 percent.

Poor ride quality or excessive vibration is perceived by drivers of large trucks as a significant problem. Wilson and Horner (1979) surveyed 3,600 Teamster truck drivers and found that 36 percent believed that cab vibration either caused major discomforts or created serious problems that made it difficult to drive the truck safely. More drivers seemed aware of vibration when driving their vehicles empty (71 percent) than when their vehicles were loaded (47 percent). The drivers surveyed reported they had been involved in 1,667 accidents over the previous five years, 14 percent of which they attributed in part to poor ride quality.

Ride quality is not a well understood phenomenon. The measurement and interpretation of truck cab vibrations and the determination of acceptable levels for safety and driver health are subject to differing views within the safety community.

Vehicle Conspicuity

In 1980, 1,368 fatal accidents involved an impact into the side or rear of a large truck and resulted in 1,598 fatalities (FARS data, 1980).

A study of a sample of fatal side- and rear-impact truck accidents (Minihan and O'Day, 1977) found that such accidents could be characterized as (1) occurring more often at night, (2) resulting from the driver of the striking vehicle having been "surprised" by the presence of a large truck which he did not see in time to perform evasive maneuvers, and (3) involving high impact velocities. The authors concluded that increasing the conspicuity of large trucks, particularly at night, could decrease the number of fatal car-into-truck side and rear collisions.

These findings have encouraged continued research into the effectiveness and desirability of equipping the rear and sides of large trucks with passive retro-reflective materials. NHTSA is experimenting with large-truck conspicuity.

Methods of enhancing motorist awareness of slow-moving large trucks on grades was studied by Lum (1979) on a two-lane rural highway. He concluded that:

- Roadway signs are ineffective as warning devices during hazardous overtaking; and

- Four-way flashers on trucks are effective both during daylight and night hours in reducing the risk of accidents when such vehicles are overtaken by faster vehicles.

The effectiveness of four-way flashers on slow-moving trucks was further investigated in a controlled field test by Knoblauch and Tobey (1980). Their results suggest that four-way flashers can reduce the likelihood of rear-end collisions.

Visibility

Truck design plays a major role in determining how much of the surrounding environment is visible to the driver. The size and location of windshields and windows determine how much can be seen directly; the size, location, number and style (plane or curved) of rearview mirrors determine indirect visibility.

Direct visibility to the rear is impossible in most large trucks because the load or trailer obstructs vision. Lack of visual information from the sides and rear of the vehicle may result in accidents while passing, turning or changing lanes. For cab-over-engine truck configurations, the height of the drivers' eyes above the road, the width of the cab, and the height of the windowsill on the passenger side frequently combine to create a "blind spot" in the right-front quadrant large enough to conceal a full-sized passenger car. In cab-behind-engine tractors, the driver sits lower, in a narrower cab and, consequently, the right-front "blind spot" is smaller. However, in some cabs with long hoods the driver may be unable to see the road directly in front of his vehicle.

The limitation on direct visibility places much of the burden of satisfying the drivers' need for visual information on mirrors. As a result, truck mirror systems have proliferated. These use a wide variety of placement choices in locating plane and convex mirrors of differing sizes and shapes. Drivers who are assigned daily to different trucks must adjust to each new mirror system and its performance characteristics.

Evidence indicates that the amount of time a driver's eyes are diverted from the forward roadway to mirrors varies considerably among mirror systems. Although the number of mirror glances and glance durations are thought to have safety implications, the relationship of these secondary criteria to accident involvement has not been established.

Decreased visibility resulting from inadequate defrosting and defogging of windshields, side windows, and outside rearview mirrors is a common complaint voiced by drivers of large trucks (NHTSA, 1979). Federal regulations require all vehicles, including large trucks, to be equipped with a windshield defrosting and defogging capability. The regulation establishes performance requirements for the defrost/defog system in passenger vehicles but similar performance requirements do not exist for large trucks.

Controls and Displays

Controls and displays that differ from vehicle to vehicle or that have poor human-engineering designs may lead to inadvertent control operations, delays in operating controls, and distraction of the driver's attention from the road. These problems can be more acute for drivers of large trucks than for passenger car drivers because many drivers switch from vehicle to vehicle more often than do most passenger car drivers and trucks contain more controls than do cars. Various groupings of large trucks have about 52 controls, whereas light trucks and cars generally have about 33. Large trucks have about 34 displays, whereas light trucks and cars have about 17.

Indirect evidence from experimental studies indicates that drivers take longer to find and operate controls in unfamiliar vehicles. Complaints from fleet drivers, who are likely to be assigned a different truck each day, also suggest there are safety problems associated with controls and displays.

Hazardous Materials Transportation

Hazardous materials are defined in the Hazardous Materials Transportation Act of 1974 as substances or materials in a quantity and form which may pose an unreasonable risk to health, safety, and property. Such substances include explosives, radioactive materials, liquified petroleum gas, liquified natural gas, poisons, etiologic agents, and liquid and solid flammables. The Vallette et al. (1981) study showed that 3.2 percent of 1,146 accidents investigated involved hazardous cargos, with flammable liquids being the most frequent cargo involved. Also, Philipson et al. (1978) reported that 2.6 percent of 2,923 truck accidents recorded in California involved hazardous material.

Accidents that involve trucks hauling hazardous materials are of particular concern because of the potentially serious consequences of post-cargo spillage. Post-crash fires, explosions, toxic spills, and other environmental disruptions can endanger a great many of people. A BMCS study (1977) reported that truck accidents involving hazardous cargos resulted in 22 percent more fatalities per accident and 61 percent greater property damage per accident than did all other truck accidents.

HIGHWAY/ENVIRONMENTAL-RELATED CONTRIBUTING FACTORS

Road types differ and some highway features are associated with higher accident risks than others. Environmental and temporal factors also influence both the occurrence and consequences of highway accidents. FHWA considers full control of access the most important highway safety feature. A high percentage of large-truck traffic uses the Interstate System, where access is fully controlled. In 1979 the Interstate System experienced a fatality rate 60 percent lower and an injury rate 73 percent lower than non-Interstate roads (FHWA, 1981). If reported Interstate fatality and injury rates had been as high as those on other roads in 1979, 6,700 more persons would have died and 510,000 more persons would have been injured.

Large-scale improvement of the overall highway environment is not usually feasible as a countermeasure against truck accidents because of the massive size and cost of such an undertaking. Even though access control has been shown to be very effective in reducing accidents, for example, full control of access is not practical on most roads. Similarly, upgrading all guardrails and bridge rails to restrain large trucks would not be feasible because of the many thousands of miles of existing guardrails and bridge rails. However, highway improvements applied selectively to high-risk locations and elements can effectively reduce the frequency and severity of traffic accidents, including truck accidents. Examples of such improvements are changes in the geometrics of freeway exist ramps and curves, shoulder widening, roadside clearing, and installation of high-performance barriers. Such highway improvements at high-risk truck accident locations can be highly cost effective.

Roadway Type

Two roadway classifications important to analyses of safety features are freeway versus nonfreeway and rural versus urban. Table IV-20 presents accident rates for large trucks, nontrucks, and total traffic by roadway type and location. Accident rates for all groups were consistently higher in urban locations and on nonfreeways than they were in rural locations and on freeways. The rural freeways, with lower average daily traffic, had the lowest accident rates for all vehicle types. A study by Cirillo et al. (1970) provides nationwide comparisons of overall accident rates which demonstrate the benefits of full control of access and other aspects of freeway-type design.

Specific roadway features which may affect truck safety are discussed later. It is important to note here, however, that because the type of roadway significantly influences the rate of accidents involving large trucks, and because truck exposure can vary greatly by roadway type, future evaluations of the relative safety of various truck types or operations should be controlled for roadway type.

Interchanges

The study by Vallette et al. (1981) found that 16 percent of the truck accidents on freeways occurred within the area of the interchange (10 percent for rural freeways; 21 percent for urban freeways). The study also indicated that large trucks have more accidents at off-ramps than at on-ramps. This result is consistent with other research (Cirillo et al., 1969) which showed that the accident rate at off-ramps in most cases was higher than the rate at on-ramps. BMCS data (1979) showed that the ratio of off-ramp to on-ramp accidents involving trucks was 840:701. More collision accidents occurred at on-ramps, and more non-collision accidents occurred at off-ramps. The high

TABLE IV-20

ACCIDENT RATES* BY VEHICLE TYPE
AND ROADWAY TYPE

	Roadway Type			
Vehicle Type**	Rural Freeway	Rural Nonfreeway	Urban Freeway	Urban Nonfreeway
Total Traffic	90	261	359	492
Nontrucks	87	269	365	507
Total Large Trucks	112	234	273	302

*Accidents per 100 million vehicle miles of travel
**Based on California and Michigan data only

Source: Vallette et al. (1981)

percentage of rollover accidents at ramps also suggests that truck speeds frequently exceed ramp design speeds. At both on- and off-ramps, at least 25 percent of all accidents involving large trucks resulted in an overturned truck. In only 7 percent of non-ramp accidents involving large trucks did the truck overturn.

Intersections

The study by Vallette et al. (1981) found that the percentages of accidents involving large trucks that occurred or were related to intersections were 65 and 23 percent for urban and rural nonfreeways, respectively. The O'Day et al. (1980) analysis of five years of FARS data showed that 23.8 percent of the fatal accidents involving combination trucks occurred within an intersection, another 1.7 percent were considered intersection-related, and 4.7 percent occurred near a driveway, alley or other road-access point. Analysis of North Carolina data showed that almost 33 percent of the accidents involving large trucks occurred at intersections and another 13.5 percent at driveways and alley intersections (Lohman and Waller, 1975). Table IV-21 shows that single-unit trucks were involved in fatal accidents at junctions more often than were other vehicle types.

Grades

Large trucks encounter special safety risks on grades. On upgrades they are subject to being struck in the rear by overtaking vehicles, and on downgrades they are susceptible to "runaway" accidents, or overtaking and striking slower vehicles. Scott and O'Day's (1971) analysis of truck accidents on grades of the Ohio and Pennsylvania Turnpikes revealed that large trucks were more often

TABLE IV-21

PERCENT FATAL ACCIDENTS AT JUNCTIONS AND NON-JUNCTIONS
BY VEHICLE TYPE

	Vehicle Type			
	Passenger Car	Light Truck or Van	Single-Unit Truck	Combination Truck
Junction*	30.8	29.3	42.5	32.7
Non-Junction	69.2	70.7	57.5	67.3

*Junction includes intersections, interchanges, driveway, alleys, railroad grade crossings, and crossovers.

Source: FARS (1980)

the struck vehicle on the steeper upgrades and cars were more often the struck vehicle on downgrades. The truck accident study by Vallette et al. (1981) reported that:

- The ratio of truck accidents on upgrades to those on downgrades was about 1:1 except on rural nonfreeways, where trucks had a higher proportion of downgrade accidents than upgrade accidents (25 percent versus 15 percent); and

- Steep downgrades on urban roadways, particularly nonfreeways, had a greater incidence of truck accidents than lesser slopes or corresponding upgrades.

The O'Day et al. (1980) analysis of five years of FARS data showed that 31 percent of the fatal accidents involving combination trucks occurred on grades. Steep upgrades occasionally have climbing lanes for larger, slower vehicles. These are installed primarily to improve traffic flow and capacity and little attention has been paid to their possible safety effects. Scott and O'Day (1971) compared the rate of accidents in climbing lane segments of the Pennsylvania Turnpike to the rate for similar grades without climbing lanes. Findings were inconclusive because of insufficient data.

Lill (1977) found that about 6 percent of 497 BMCS-reported accidents studied involved "runaway" trucks on downgrades. He also indicated that the factors most prevalent in downgrade accidents, aside from grade geometry, were failure to downshift and defective brakes.

In developing warrants for the use and location of truck escape ramps, Eck (1980) analyzed some 600 accidents and found that:

- "Runaway" truck accident rates increased with the steepness of the grade;

- o Routes with low percentages of truck traffic had the highest "runaway" truck accident rates; and

- o Routes with the lowest volumes of traffic had the highest truck accident rate.

What is not available from the work of Eck (1980) or other research by Williams (1978) and Erickson (1980) is analysis of the effectiveness of truck escape ramps in reducing the frequency and severity of truck "runaway" accidents. Though the studies provided data to substantiate the use of truck escape ramps, no data have been collected to measure effectiveness. However, the studies did report accidents which occurred because drivers of "runaway" trucks unsuccessfully attempted to "ride it out" rather than use escape ramps.

Various signing techniques have been used to advise unfamiliar truck drivers about the nature of the grade (length, curvature, and gradient) and the recommended speed. Research by Meyers et al. (1980) showed that a rating system based on grade length and steepness is feasible and signs were developed to advise truck drivers of the safe descent speed on a grade based on the gross weight of his truck. Those which have proven effective under experimental conditions will soon be tested on highway downgrades.

Curves

The Vallette et al. (1981) study found that accidents involving large trucks on curves ranged from a low of 7 percent for urban nonfreeways to a high of 34 percent for rural nonfreeways. Overall, 20 percent of the accidents in the sample occurred on curves, but the mileages for curved and straight portions of the roadways used in the study were unknown. As a result, the over- or under-involvement of large trucks in accidents on curves could not be determined.

Bondy and Partyka (1980) analyzed 1979 FARS data for accidents involving combination trucks in which the truck driver was killed. Forty-five percent of the single-vehicle accidents occurred on curved sections of roadway as compared to only 16 percent of the multiple-vehicle accidents.

Shoulders

BMCS (1977) conducted a study of 2,006 accidents involving motor carriers under its jurisdiction. The accidents occurred between 1967 and 1975. Three percent involved a vehicle stopped on the shoulder of a highway. Of these, 43 percent were trucks. Ninety percent of these on-shoulder accidents were rear-end collisions and resulted in more fatalities and injuries per accident than the total sample of accidents.

Other findings of the BMCS analysis:

- Sixty-two percent of on-shoulder accidents occurred during darkness; and
- Drivers dozing at the wheel were identified as the primary cause in 53 percent of the on-shoulder accidents.

Sight Distance

Stopping sight distance is the distance travelled by a vehicle from the instant its driver sights an object which requires a stop to the instant the brakes are applied, plus the distance required to stop the vehicle after brake application. At present, crest vertical curves (where road alignment changes from uphill to downhill) are usually designed to give the automobile driver sufficient sight distance to bring his vehicle to a safe stop. It has generally been asummed that the higher eye height afforded drivers in trucks compensated for the longer distance required to stop a truck.

This assumption was critically examined by Gordon (1979). He evaluated sight distance requirements for crest vertical curves, passing zones, and sag vertical curves (where road alignment changes from downhill to uphill) for different types of trucks and cab configurations.

Crest Vertical Curves: Gordon concluded that increased eye height compensates for inferior truck braking for the average of all truck sizes, but does not hold true for larger and heavier trucks that have longer braking distances. FHWA is further studying the extent of stopping sight distances required by trucks.

Passing Zones: Others have reported that trucks, on average, require 50 percent more distance to pass other vehicles than do nontrucks. Gordon concluded that this was not adequately compensated for by the truck driver's 17 to 27 percent sight distance advantage and that lengths of passing zones, standardized for passenger cars, are inadequate for trucks.

Sag Vertical Curves: Sight distance in this instance is determined by headlight range. Gordon concluded that the truck driver has no unusual visibility disadvantage.

Roadside Features

Vehicle collisions with roadside objects were reported by FARS to be the first harmful event in 33 percent of all fatal accidents in 1980, as compared to multiple-vehicle collisions (38 percent) and vehicle accidents involving pedestrians (18 percent). Considerable effort has gone into development of more forgiving roadside features and protective devices to reduce this toll. Most of this effort has focused on improved safety for passenger cars because (1) they represent the majority of the vehicles on the road, and (2) until the mid-1970s the development of barriers to contain heavier vehicles was thought unfeasible.

Breakaway supports for signs and luminaries pose no problems for large trucks. If a breakaway device performs properly when struck by an automobile, it will perform properly when struck by a large truck. (The increasing population of smaller and lighter passenger cars on the roadway does create concern about the adequacy of breakaway devices for those vehicles, however.)

Standards used in the development of crash cushions specify acceptable performance for vehicles weighing between 2,250 and 4,500 pounds. A recent study (Labra, 1979) has shown that it is not feasible with current technology to develop impact attenuators for combination trucks.

Traffic barriers (guardrails, bridge rails, and median barriers) now on highways have also generally been developed for passenger vehicles. It is not uncommon for large trucks, because of their weight and high center of gravity, either to penetrate a traffic barrier or to overturn upon impact rather than be redirected upright and on a non-collision course. In a limited sample (68 cases) of truck accidents involving guardrails (Vallette et al., 1981), 36 percent of the trucks that struck guardrails mounted on wooden posts penetrated or vaulted the guardrail compared to 19 percent for guardrails with steel posts. VanZweden and Bryden (1979) found that vehicle penetration of weak-post guardrail and median barrier designs occurred in 16 percent (57 of 347 cases) of impacts by vehicles weighing less than 5,000 pounds, and in 43 percent (20 of 47 cases) of impacts by vehicles weighing more than 5,000 pounds. The sample did not include impacts within 50 feet of either end of the railing. Other evidence of the inadequancy of guardrails and barriers for trucks was cited by Post et al. (1973), who reported that the number of trucks involved in traffic-barrier fatal accidents in Texas increased from 16 to 21 percent over a two-year period in the early 1970s.

This concern has prompted impact-testing of large trucks into these protective devices. Post et al. (1973) did preliminary testing by running a loaded combination truck weighing 48,000 pounds into a concrete safety-shaped barrier (commonly referred to as the New Jersey barrier) at speed and approach angle combinations of 35 mph and 19 degrees, 34 mph and 15.5 degrees, and 45 mph and 15 degrees. The barrier proved effective for all three tests, and only minor damage occurred to both truck and barrier.

Research has established the upper performance limit of concrete safety-shaped barriers (DSI, 1981). In a 40,000-pound, cab-over-engine combination-truck impact at 55 mph and 15 degrees, the tractor and the front of the trailer climbed the top of the barrier. The position of the vehicle after the crash suggested that complete vaulting of the tractor and, possibly, the trailer could be expected in a collision with a barrier longer than the section employed in the test.

FHWA research on barrier systems for heavier vehicles has primarily concentrated on school buses and intercity buses because of the consequence of serious injuries and fatalities to a larger number of people when such vehicles penetrate or vault a traffic barrier (TTI, 1982). Problems associated with the difficulty of containing combination trucks and of stable redirection (e.g., truck-load shift, fully-loaded combination trucks and rollover) have not been addressed rigorously.

FHWA has a program to develop improved bridge railing systems for heavier vehicles (FCP Project 1T, 1981). One project evaluated an energy-absorbing system which used the deformation of steel rings as the primary energy absorber. Kimball et al. (1976) conducted three crash tests using combination trucks weighing 40,000 and 70,000 pounds. Although the vehicle was contained and redirected in each test, it overturned.

Studies of the dynamics of truck impacts into guardrails, barriers, and other protective systems is continuing at FHWA (TTI, 1982). An effort by FHWA and the New Jersey Turnpike Authority is aimed at developing a high performance median barrier capable of successfully redirecting an 80,000-pound combination truck without rollover.

Effect of the 55 MPH Speed Limit

Solomon (1964) concluded that the greater the variation in speed of any vehicle from the average speed of all traffic, the greater its chance of being involved in an accident. One of the effects of the 55 mph national speed limit implemented in 1974 has been to reduce the speed differential between cars and trucks. A reduction in the incidence of car-truck collisions could be presumed to have occurred as a result.

Zaremba and Ginsburg (1977) examined accident data from police-reported crashes during two years in Maryland, North Carolina, Pennsylvania and Texas to determine the change (if any) in the frequency of front-to-rear collisions as a result of the mandatory 55 mph speed limit. From accident data files they were able to distinguish front-to-rear crashes involving (1) two automobiles, (2) one automobile and one combination truck, and (3) one automobile and one single-unit truck. High- and low-speed roadways were considered separately. Their results are illustrated in Figure IV-11.

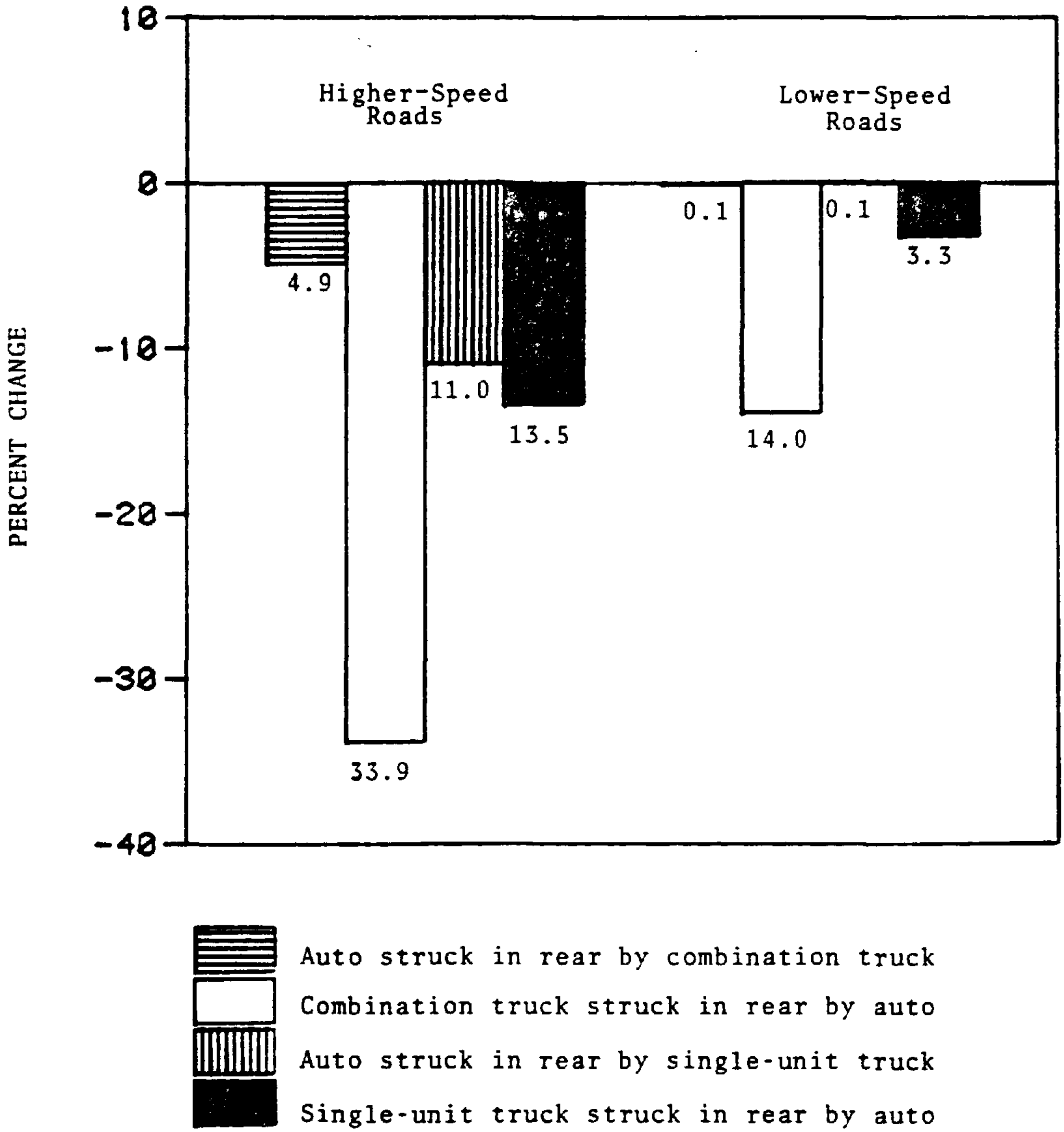
The number of front-to-rear crashes involving automobiles and trucks decreased from 1973 to 1974, especially on higher-speed roads. Most notable was a decrease of nearly 34 percent in the number of combination trucks struck in the rear by automobiles on higher-speed roads. The decreases were observed despite the fact that, as the researchers noted, combination-truck travel increased in the States considered by an estimated 13 percent on main rural roads in 1974. The authors concluded that the large decline in the number of crashes in which automobiles struck combination trucks in the rear, and the small decline in the number of crashes in which combination trucks struck automobiles in the rear, was the result of the combined effects of the decreases both in the speeds of and speed differentials between these vehicles.

Two studies (Radwan, 1976 and Radwan and Sinha, 1978) examined the effect of the 55 mph speed limit on truck accidents in Indiana for three classes of rural highways--Interstate, four-lane, and two-lane. Accident rates were

FIGURE IV-11

OVERALL PERCENTAGE CHANGE IN

FRONT-TO-REAR CRASHES, 1973-74



Source: Zaremba and Ginsburg (1977)

determined for six 6-month periods before the national speed limit was enacted and for three 6-month periods after. Truck exposure was calculated from State traffic and vehicle classification counts. The first analysis (1976) determined that:

- Average large-truck accident rates on Interstate and other four-lane highways decreased significantly as a result of the 55 mph speed limit;

- The rate of rear-end collisions involving large trucks decreased significantly on Interstate and other four-lane highways but not on two-lane highways; and

- The rate of front-to-side accidents involving large trucks decreased significantly on non-Interstate four-lane and on two-lane rural highways.

The second report (1978) analyzed large-truck accident rates by severity. The researchers found that accident rates decreased for all severity levels (property damage, nonfatal injury, and fatality) on Interstate highways. On other four-lane and two-lane rural highways, a significant decrease was observed only for accidents that resulted in nonfatal injuries.

The researchers attributed the reductions observed in the two studies to an absolute reduction in speeds and to the decreased speed differental between large trucks and passenger automobiles.

<u>Signal and Sign Visibility</u>

A large vehicle obstructs the forward vision of motorists in smaller vehicles behind them. While no accident information is available to substantiate that this poses a significant safety problem, some analytical work has been done. Abramson (1971) developed a mathematical model to determine the probability that a driver's view of a roadside sign will be blocked by a truck or trucks ahead. The model considers the number of lanes, lane width, position and size of the sign, truck length and speed, angle of the driver's line of sight, and car speed. The model can be used to determine when to install overhead signs as well as for evaluating devices that rely on line-of-sight.

King et al. (1976) examined traffic signal visibility through simulation experiments and analysis. The validated analytical model was used to determine the extent of expected visibility blockage as a function of signal location, traffic volume, and traffic mix. Truck length, width, and height were also considered. Only truck height was found to affect significantly the visibility of traffic signals. As expected, blockage of signal visibility was found to increase as traffic volume increased, as the number of trucks increased, and as average traffic speed decreased. It was concluded that the addition of a far-left, post-mounted traffic signal would considerably reduce truck blockage of signals, and that increasing the height of traffic signals to the maximum permitted would be less effective.

Environmental Characteristics

-- Time of Accident

Data from six sources show a reasonably consistent pattern for total accidents and fatal accidents involving large trucks by time-of-day, day of the week, and month of the year. Table IV-22 presents these data by hour-of-day. Truck accidents during late night and early morning were found to be more likely to have fatal results than were those during other time periods but because no exposure data (VMT) were available by time-of-day, day of the week, or month of the year, interpretations regarding over- or under-involvement of large trucks in accidents would be meaningless. Accident characteristics for these time periods could be only a reflection of travel patterns.

TABLE IV-22

PERCENT DISTRIBUTION OF TRUCK ACCIDENTS BY HOUR OF DAY

	ACCIDENTS					FATAL ACCIDENTS		
HOUR OF DAY	BMCS[1] 1978	Six States[2] 1976-77	Seven States[3] 1978	Calif.[4] 1970-71	NASS[5] 1979-1980	FARS[6] 1979	FARS[6] 1980	BMCS[1] 1978
0000-0300	8.7	7.0	5.6	7.0	2.9	10.8	11.4	14.8
0300-0600	9.4	9.0	4.0	4.8	1.7	8.7	8.8	12.4
0600-0900	13.4	13.0	13.8	13.3	14.7	11.8	11.7	12.2
0900-1200	16.4	18.0	19.3	17.9	20.1	15.3	14.0	10.0
1200-1500	16.6	17.0	21.2	20.2	22.0	16.3	16.5	13.8
1500-1800	16.8	18.0	20.8	20.1	24.0	15.3	16.5	13.7
1800-2100	10.1	10.0	8.7	9.0	9.5	11.1	10.3	11.7
2100-2400	8.0	8.0	6.5	7.4	4.9	10.7	10.7	11.4
Unknown	--	--	--	--	0.2	--	--	--

Sources: [1]BMCS (1978), values are for time increments 1/2 hour earlier, e.g., 8.7% is for 2330 to 0230
[2]Vallette et al. (1981), six States of study were California, Maryland, Michigan, Nevada, Pennsylvania, and Texas.
[3]Najjar (1981), injury accidents only for North Carolina, Maryland, New York, Michigan, Colorado, Washington, and California.
[4]Zieszler (1973)
[5]NASS (1979-1980) Annual Average
[6]FARS (1979-1980)

-- Light Conditions

The distributions of truck accidents and fatal truck accidents under various light conditions are shown in Table IV-23. These distributions are, of course, similar to those of accidents by hour-of-day and similarly indicate that large-truck accidents during darkness were more severe, inasmuch as BMCS data show that 27 percent of all truck accidents (those which occurred during darkness) accounted for 40.7 percent of all fatal accidents that involved trucks. Again, without exposure data (VMT) of truck travel based on light condition, it is not possible to determine the relative hazard for various light conditions.

-- Weather and Pavement Condition

The percentage of truck accidents that occurred during adverse weather conditions varied from 14 percent to 27 percent in the set of six samplings in Table IV-24. The variation probably reflects geographic and climatic differences. The NASS estimate of about 22 percent contrasts with 20 percent of the passenger car accidents which occur during adverse weather conditions (NASS data, 1979-1980). In Cassidy's (1978) analysis of 1976 FARS data, he found that large trucks were involved in only 8 percent of all fatal accidents but in 16 percent of all those during snowfall or sleet, 10 percent of those during rain, and 16 percent of those during fog, smoke, or smog. As noted by Li et al. (1979), the greater likelihood that a fatal accident involving a large truck would occur during inclement weather could be attributed in part to the fact that trucks often operate regardless of weather conditions in order to meet schedules. However, it could also be influenced by the performance ability of large trucks on wet and slippery pavements.

Pavement condition is a result of weather, and distributions of accident rates based on the two variables should be similar. Similarity does indeed exist when the distribution of truck accidents by pavement condition (Table IV-25) is compared to the distribution by weather condition (Table IV-24). When data from BMCS and from Lohman and Waller (1975) were examined by accident type, wet or icy pavement conditions accounted for a greater incidence of single-vehicle accidents than of multiple-vehicle accidents.

TABLE IV-23

PERCENT DISTRIBUTION OF TRUCK ACCIDENTS BY LIGHT CONDITION

	ACCIDENTS				FATAL ACCIDENTS		
LIGHT CONDITION	BMCS[1] 1978	Six States[2] 1976-77	North[3] Carolina 1973	NASS[4] 1979-1980	FARS[5] 1979	FARS[5] 1978	BMCS[1] 1980
Day	61.3	63	74.0	84.9	57.5	57.8	46.0
Dawn or Dusk	7.1	6	3.4	2.0	4.4	3.6	8.9
Dark	27.0	23	15.7	7.6	31.0	31.0	40.7
Dark, Lighted	3.5	8	3.6	5.5	7.0	7.5	3.5
Other*	0.9	--	3.3	--	0.1	0.1	0.8

*Other also includes the categories of "multiple" and "not stated".

Sources: [1]BMCS (1978)
[2]Vallette et al. (1981), six states of study were California, Maryland, Michigan, Nevada, Pennsylvania, and Texas.
[3]Lohman and Waller (1975)
[4]NASS (1979-1980) Annual Average
[5]FARS (1979-1980)

TABLE IV-24

PERCENT DISTRIBUTION OF TRUCK ACCIDENTS BY WEATHER CONDITION

	ACCIDENTS					FATAL ACCIDENTS	
WEATHER CONDITION	BMCS[1] 1978	Six States[2] 1976-77	Calif.[3] 1970-71	North[4] Carolina 1973	NASS[5] 1979-1980	FARS[6] 1979	FARS[6] 1980
Clear, Cloudy	70.0	77	87.7	80.0	78.1	83.1	84.6
Rain	14.9	11	--	13.1	15.1	10.7	9.4
Snow	8.3	7	10.2	1.5	4.5	2.7	3.1
Fog/Smog	2.3	--	--	2.0	0.9	2.7	2.0
Sleet	1.2	1	--	0.2	0.1	0.3	0.3
Other*	2.6	4	1.3	1.0	1.3	0.5	0.6

*Other also includes the categories of "multiple" and "not stated".

Sources: [1]BMCS (1978)
[2]Vallette et al. (1981), six states of study were California, Maryland, Michigan, Nevada, Pennsylvania, and Texas.
[3]Zeiszler (1973)
[4]Lohman and Waller (1975)
[5]NASS (1979-1980) Annual Average
[6]FARS (1979-1980)

TABLE IV-25

PERCENT DISTRIBUTION OF TRUCK ACCIDENTS BY PAVEMENT CONDITION

<table>
<tr><th></th><th colspan="5">ACCIDENTS</th><th colspan="2">FATAL ACCIDENTS</th></tr>
<tr><th>PAVEMENT CONDITION</th><th>BMCS[1] 1978</th><th>Six States[2] 1976-77</th><th>Calif.[3] 1970-71</th><th>North[4] Carolina 1973</th><th>NASS[5] 1979-1980</th><th>FARS[6] 1979</th><th>FARS[6] 1980</th></tr>
<tr><td>Dry</td><td>65.8</td><td>72</td><td>87.2</td><td>75.8</td><td>72.0</td><td>77.6</td><td>81.3</td></tr>
<tr><td>Wet</td><td>17.9</td><td>16</td><td>10.6</td><td>17.5</td><td>21.0</td><td>15.9</td><td>13.1</td></tr>
<tr><td>Snowy</td><td>4.7</td><td rowspan="2">12</td><td rowspan="2">0.9</td><td>1.4</td><td>1.9</td><td>2.8</td><td>2.5</td></tr>
<tr><td>Icy</td><td>8.9</td><td>1.9</td><td>3.7</td><td>3.1</td><td>2.6</td></tr>
<tr><td>Other*</td><td>2.7</td><td>--</td><td>1.3</td><td>3.4</td><td>1.4</td><td>0.6</td><td>0.5</td></tr>
</table>

*Other also includes the categories of "multiple" and "not stated".

Sources: [1]BMCS (1978)
[2]Vallette et al. (1981), six states of study were California, Maryland, Michigan, Nevada, Pennsylvania, and Texas.
[3]Zeiszler (1973)
[4]Lohman and Waller (1975)
[5]NASS (1979-1980) Annual Average
[6]FARS (1979-1980)

SECTION V

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This section summarizes current knowledge about the causes of large-truck accidents and the injuries that result from them. Supporting material for each finding and conclusion is referenced by page number in this report. The findings and conclusions are followed by recommendations about what should be done by motor carriers, truck manufacturers, government agencies, insurers and drivers. The section concludes with an enumeration of research and development efforts needed to achieve a more thorough understanding of large-truck accidents and to develop effective countermeasures.

FINDINGS AND CONCLUSIONS

The U.S. Trucking Industry

1. About 20 percent of the estimated 27 million trucks in use in the United States in 1977 were large trucks. These represented 4.0 percent of all registered vehicles and accounted for 6.7 percent of all vehicle miles travelled (p. II-7).

2. Although combination trucks travel as many miles a year as single-unit trucks, there are only one-fifth as many combination trucks as single-unit trucks (p. II-8).

3. Significant differences exist in scheduling and maintenance procedures and mileages driven among various segments of the trucking industry (p. II-13).

Truck Accident Experience

4. In 1979-1980 accidents involving large trucks accounted for about 5.7 percent (385,000) of all police-reported accidents and 12.4 percent (6,332) of all traffic fatalities. In 1980 large-truck accident

fatalities dropped to 11.7 percent (5,968) of all traffic fatalities and for 1981 the number of fatalities declined to 5,779 but the proportion of all traffic fatalities has remained the same. The recent decline in fatalities may be attributable to reductions in miles of travel (pp. III-1, III-17, III-18 and III-22).

5. Large trucks were involved in fewer traffic accidents per mile of travel than were passenger cars--474 truck involvements versus 825 car involvements per 100 million vehicle miles of travel (p. III-4).

6. Large trucks experienced almost twice the fatal accidents per mile of travel than did passenger cars, and combination trucks were involved in fatal accidents at a rate of more than three and one-half times that of single-unit trucks (p. III-5).

7. One of every 12 large trucks and one of every 3 combination trucks are involved in an accident each year, compared to one of every 13 passenger cars. These differences are attributable, at least in part, to differences in average miles travelled (p. III-4).

8. When a passenger car is involved in a fatal accident with a large truck, the car occupant is 29 times more likely to be killed than the truck occupant. The risk of death to occupants of passengers cars involved in fatal accidents with large trucks increased each year from 1977 to 1980 (p. III-24).

9. The number of fatal accidents that involved large trucks increased annually from 1976 to 1979, then declined by 11.3 percent in 1980 and declined another 2.7 percent in 1981. The number of persons killed in accidents involving large trucks also declined. Historically, such reductions have accompanied economic slowdowns (pp. III-17 and III-18).

10. Fatalities that result from large-truck accidents will continue to represent 11-14 percent of all traffic fatalities through the 1980s, although large trucks will account for only about 7 percent of the nation's vehicle miles travelled (pp. III-1 and III-25). Thus, the severe consequences of large-truck collisions with automobiles, especially small passenger cars, are and will continue to be a major safety problem (p. III-28).

11. The following trends are expected to continue during the current decade:

    - Large passenger car mileage will decrease;
    - Small passenger car mileage will increase;
    - Large-truck mileage will increase;
    - The number of registered vehicles will increase;
    - Annual accidents and fatalities will increase;
    - Large-truck accidents and resulting fatalities will increase;
    - Traffic density will increase because construction of new highway mileage will increase only slightly compared to the increase in vehicles registered (pp. III-21 to III-28).

Driver-Related Factors

12. Drivers of large trucks who are younger than 25 appear to be more overinvolved in accidents than are passenger car drivers under 25 (p. IV-9).

13. The majority (85 percent) of drivers of large trucks involved in accidents have had no formal commercial driver training (p. IV-14).

14. Although no direct relationship exists between accidents and hours-of-service, drivers of large trucks have been shown to experience significant increases in driving errors and decreases in driver alertness due to fatigue well within the ten-hour limit allowed by BMCS regulations (pp. IV-15 to IV-20).

15. Use of alcohol appears less prevalent among accident-involved drivers of large trucks than among accident-involved passenger car drivers (pp. IV-20 and IV-21).

16. Accurate assessments of the number of drivers of large trucks who have multiple licenses or multiple driving records are not available (pp. IV-24 to IV-27).

Vehicle-Related Factors

17. Available evidence is conflicting on whether or not the accident rates per mile of travel differ between single-trailer and double-trailer combination trucks (pp. IV-29 to IV-34).

18. Combination trucks, especially double-trailer combinations, appear to have higher accident rates when running empty or near empty than when running loaded (pp. IV-44 to IV-49).

19. Single-unit and combination (single-trailer) dump trucks and double-trailer tank trucks are more likely to be involved in an accident than other large-truck configurations. This may be attributable, in part, to operating and maintenance practices (p. IV-40).

20. Truck rollover is the harmful event most frequently attributed to fatalities among occupants of large trucks (p. IV-50).

21. More than one-third of all occupants of large trucks killed in accidents were ejected from the cab (p. IV-50).

22. About 97 percent of all fatally injured truck occupants were not wearing safety belts, the same rate as for fatally injured passenger car occupants (p. IV-50).

23. Cab-over-engine tractors experience higher truck-driver fatality rates than do cab-behind-engine tractors. This may be attributable in part to differences in operating practices (p. IV-51).

24. Large trucks required greater stopping distances than passenger cars. Empty combination, single-unit trucks and "bobtails" also experienced instability problems during braking (p. IV-58).

25. More than 40 percent of the large trucks selected for inspection by State and Federal agencies are taken out of service because of defective equipment. About half of these equipment defects were in the truck-braking system. Many defects can be found by visual inspection by drivers themselves (p. IV-62).

26. Proper inspection and maintenance of large trucks resulted in reduced rates of involvement in defect-related accidents. Operators of large fleets tend to employ more thorough maintenance practices than do operators of smaller fleets (p. IV-63).

27. Four-way flashers on slow-moving large trucks appear to reduce the likelihood of rear-end collisions (p. IV-71).

Highway/Environmental-Related Factors

28. The safety benefits of full control of access (e.g., the Interstate System) apply as well to trucks as to all other vehicles (p. IV-75).

29. More truck rollovers occur in large-truck accidents at freeway on- and off-ramps than in accidents at other locations (pp. IV-76 and IV-78).

30. Accidents involving large trucks occur more frequently at freeway off-ramps than at on-ramps (pp. IV-76 and IV-78).

31. Fatal accidents that involve combination trucks appear to occur more frequently on highway grades than on level sections (pp. IV-78 and IV-80).

32. Many more of the most serious large-truck single-vehicle accidents occur on curved sections of highway than on straight sections (pp. IV-81 and IV-82).

33. Criteria used to establish and mark passing zones on two-lane roads often do not accommodate large-truck sight distance requirements (p. IV-83).

34. Roadside protective systems such as guardrails, median barriers and impact attenuators generally are not designed to accommodate large-truck impacts; in some instances it may not be cost-effective to provide such protection for large trucks, given present technology (pp. IV-83 to IV-85).

35. The 55 MPH national speed limit appears to have reduced large-truck accident rates on multi-lane highway facilities (pp. IV-86 to IV-88).

Data Sources

36. No single source of large-truck accident data exists currently which contains both the volume of cases needed to represent national experience and the detail needed for complete causation analysis (pp. C-8 and C-9).

37. Currently available data on accident and travel characteristics severely limit understanding how relevant factors interact to influence large-truck safety (pp. C-9 and C-10).

38. Examination of factors and their relative contributions to large-truck accidents should not rely exclusively on accident data but should be complemented by analytic, laboratory and test-track research, and by on-highway evaluations (pp. C-11 and C-12).

RECOMMENDATIONS

Motor Carriers Should:

1. Ensure that drivers comply with motor carrier safety regulations (pp. IV-7 to IV-27).

2. Conduct pre-trip and post-trip truck inspections (pp. IV-62 to IV-64).

3. Implement effective truck maintenance programs emphasizing braking systems (pp. IV-62 to IV-64).

4. Improve driver qualifications through pre-employment background screening and increased training, with special attention to the training, supervision, and monitoring of young drivers, and increase training to familiarize drivers with large-truck handling and braking capabilities (pp. IV-7 to IV-14 and IV-24 to IV-27).

5. Ensure that safety belts are installed in all trucks and require their use by drivers (pp. IV-49 to IV-51).

6. Use freeway facilities wherever possible (pp. IV-75 to IV-94).

7. Consider installing devices to reduce splash and spray (pp. IV-68 to IV-69).

8. In geographic areas where new trucks will be operating in mountainous terrain, specify that they come equipped with retarders to increase reserve braking capacity (pp. IV-57 to IV-62).

9. Increase safe-driving incentive and safety management programs (p. IV-27).

10. Cooperate with State and Federal agencies in the collection and analysis of truck travel and accident experience (Appendix C).

11. Subject to individual state traffic regulations, use four-way flashers on large trucks when operating on high-speed highways at low speeds (p. IV-71).

12. Take steps to control the use of alcohol and other drugs by drivers (pp. IV-20 to IV-24).

13. Ensure that safety-defect corrections are made (p. IV-28).

<u>Large-Truck Manufacturers Should</u>:

1. Improve the braking performance of large trucks and trailers, and implement improvements to reduce in-service brake degradation (pp. IV-57 to IV-64).

2. Develop and install more comfortable and convenient safety belt systems for truck occupants (pp. IV-49 to IV-51).

3. Improve the handling capability of large trucks (pp. IV-64 to IV-68).

4. Install retarders in large trucks to enhance reserve brake capacity (pp. IV-57 to IV-62).

5. Increase large-truck conspicuity (pp. IV-70 to IV-71).

6. Improve the crashworthiness of tractor cabs (pp. IV-49 to IV-53).

7. Standardize truck controls, displays, and mirrors (p. IV-73).

8. Improve the ride quality of large trucks (pp. IV-69 to IV-70).

9. Distribute to purchasers of large trucks improved inspection, maintenance, and service instructions (pp. IV-62 to IV-64).

10. Increase sponsorship of research and development to improve large-truck safety. (Research and development needs are listed on pp. V-12 and V-13.)

11. Publicize and continue to promote the timely correction of safety-related defects (p. IV-28).

Federal Government Should:

1. Continue Federal inspection of large trucks and their drivers and encourage more widespread truck inspection by States. Publicize among motor carriers the economic and safety benefits of improved vehicle maintenance (pp. IV-28 and IV-62 to IV-64).

2. In cooperation with the truck safety community, coordinate the research and development program which complements truck accident and travel data acquisition and analysis activities. (Research and development needs are listed on pp. V-12 and V-13.)

3. Encourage States to evaluate and improve large-truck driver license testing, issuance and control practices, and foster use of the National Driver Register and the Driver License Compact (pp. IV-24 to IV-27).

4. Define in cooperation with the truck safety community the large-truck exposure (travel characteristics) and accident data that are most needed and develop and implement a coordinated plan to fill these needs (Appendix C).

5. Continue the development and promotion of improved truck-driver training programs with emphasis on younger drivers (pp. IV-7 to IV-14).

State Governments Should:

1. Increase on-road large-truck inspections and broaden authorization for removing vehicles from service (pp. IV-62 to IV-64).

2. Implement and evaluate improved truck-driver license testing and issuance procedures, and increase compliance with provisions of the Driver License Compact and participation in the National Driver Register (pp. IV-24 to IV-27).

3. Continue to join with Federal agencies in attempts to understand large-truck accident phenomena and to determine the effectiveness of alternative countermeasures (Sections III and IV).

4. Increase enforcement efforts of traffic laws relating to large trucks (pp. IV-75 to IV-94).

5. Increase familiarity with truck-driver training programs and promote use of improved programs by the trucking industry, including safety-incentive awards (pp. IV-7 to IV-14 and IV-27).

6. Promote an understanding by industry of the benefits of compliance with Federal and State Motor Carrier Safety and Hazardous Materials Regulations (pp. IV-7 to IV-74).

7. Continue to promote truck safety-defect corrections (p. IV-28).

State and Federal Government Should:

1. Promote use of safety belts by all motor vehicle occupants, specifically including occupants of large trucks (pp. IV-49 to IV-51).

2. Identify and correct the hazards associated with locations that have a high incidence of truck accidents, such as freeway on- and off-ramps, surface street intersections, grades, and curved sections of highway (pp. IV-76 to IV-82).

3. Promote safety countermeasures and safety management techniques (Section IV).

4. Adopt uniform classification and recording of large-truck travel and accident information (Appendix C).

5. Continue efforts to achieve uniformity among State and Federal motor carrier safety regulations (pp. IV-7 to IV-74).

6. Publicize the braking performance and control problems associated with empty trucks, trailers, and "bobtail" tractors (pp. IV-57 to IV-62).

<u>Insurance Companies Should</u>:

1. Expand areas of cooperation with NHTSA and FHWA on research efforts by providing available data on large-truck accidents (Appendix C).

2. Encourage truck owners to correct safety defects (p. IV-28).

3. Increase cooperative efforts with motor carriers to implement truck-safety programs (Appendix B).

4. Sponsor and conduct research and development efforts to improve large-truck safety. (Research and development needs are listed on pp. V-12 and V-13.)

<u>Truck Drivers Should</u>:

1. Wear safety belts (pp. IV-49 to IV-51).

2. Increase familiarity with large-truck maintenance problems and regularly check their trucks, especially the trucks' brake systems and tires. Insure that front-axle brakes are operative and do not defeat their function (pp. IV-62 to IV-64 and IV-68).

3. Comply with motor carrier safety regulations (pp. IV-7 to IV-74).

4. Not drive under the influence of alcohol and other drugs (pp. IV-20 to IV-24).

5. Comply with State and local traffic laws and ordinances (pp. IV-75 to IV-94).

6. Increase use of retarders when the truck is so equipped (pp. IV-57 to IV-62).

7. Travel on freeways instead of other road types wherever possible, even if slight increases in mileage result (pp. IV-75 to IV-94).

8. Participate in driver-training sessions and seminars on safe-driving practices (pp. IV-7 to IV-14).

9. Insist that safety-related defects be corrected (p. IV-28).

Important Research and Development Needs

1. Continue collection and analysis of large-truck accident and exposure (travel characteristics) data to expand knowledge of accident and injury causation (pp. IV-1 to IV-4 and Appendix C).

2. Develop and evaluate large-truck brake system modifications to reduce stopping distances and minimize loss of control (pp. IV-57 to IV-62 and IV-64 to IV-68).

3. Develop and evaluate alernative methods of improving the handling and stability of large trucks (pp. IV-64 to IV-68).

4. Evaluate truck-driver training programs and license testing procedures (pp. IV-7 to IV-14 and IV-24 to IV-27).

5. Evaluate roadway geometric design and traffic control device standards and practices as they apply to the size, weight, and configuration of large trucks (pp. IV-75 to IV-89).

6. Develop and evaluate improved safety belt systems for large trucks (pp. IV-49 to IV-51).

7. Develop and test improved roadside protective systems, such as guardrails, to increase their ability to accommodate large-truck impacts (pp. IV-83 to IV-85).

8. Develop and evaluate alternative methods of separating large-truck traffic from other traffic including reserved truck lanes on multi-lane facilities and routes dedicated to truck use during certain hours of the day or days of the week (pp. IV-78 to IV-81).

9. Develop and evaluate tractor-cab modifications to improve the protection afforded the driver in large-truck collisions (pp. IV-49 to IV-53).

10. Evaluate current warrants and design practices for truck climbing lanes on upgrades and for "runaway" truck escape ramps on downgrades (pp. IV-78 to IV-81).

11. Determine the extent to which drivers of large trucks have multiple licenses and multiple records (pp. IV-24 to IV-27).

12. Identify the role in large-truck accidents of alcohol and other drug use and of fatigue and special medical conditions (pp. IV-20 to IV-24).

13. Test and evaluate methods of increasing large-truck conspicuity (pp. IV-70 to IV-71).

14. Develop and test alternative methods of increasing fields of view afforded drivers of large trucks (pp. IV-71 to IV-73).

15. Develop and evaluate alternative methods of improving the ride quality of large trucks (pp. IV-69 to IV-70).

Abramson, P., "Blockage of Signs by Trucks," Traffic Engineering, Vol. 41, No. 7, April 1971, pp. 18-26.

American Association of Motor Vehicle Administrators (AAMVA). "Multiple Licensing and Interstate Truck Drivers -- A Problem Statement," Washington, D.C., January 1981.

Anderson, R.L.; Nidey, R.A.; McCormick, G.; and Russoniello, F., "Control of Large Commercial Vehicle Accidents Caused by Front Tire Failures," Dyn Sci-2320-75-130, Dynamic Science Division, Ultrasystems, Inc., Phoenix, Arizona, August 1975.

Baker, S.P., "Alcohol in Fatal Tractor Trailer Crashes," Proceedings, 19th Conference of the American Association for Automotive Medicine, 1975.

Belew, W.W.; Wuerdemann, H.; Horton, W.F.; Helfand, R.M.; Holter, W.H.; and Overbey, J.W., "Exploratory Analyses of the Fatal Accident Files," DOT-HS-801-787, NHTSA, Washington, D.C., December 1975.

Boehly, W.A. and Lombardo, J.V., "Safety Consequences of the Shift to Small Cars in the 1980's," Small Car Safety in the 1980's, DOT-HS-805-729, NHTSA, Washington, D.C., March 1981.

Bondy, N. and Partyka, S.C., "An Analysis of Fatalities in Articulated Trucks Using Automated Accident Data Files," National Center for Statistics and Analysis, NHTSA, Washington, D.C., June 1980.

Boyd, P.L.: Neill, A.H., Jr.; and Hinch, J.A., "Truck Tire Cornering and Braking Traction Study," DOT-HS-804-732, NHTSA, Washington, D.C., March 1979.

Bureau of Motor Carrier Safety. "Federal Motor Carrier Safety Regulations and Noise Requirements," Code of Federal Regulations (CFR), Title 49, Chapter III, Subchapter B, FHWA, Washington, D.C., October 1979.

Bureau of Motor Carrier Safety. "The Insulin-Dependent Driver," FHWA, Washington, D.C., April 1980.

Bureau of Motor Carrier Safety. "1979 Roadside Vehicle Inspections," FHWA, Washington, D.C., June 1980.

Bureau of Motor Carrier Safety. "BMCS Roadside Inspections 1976-1977," FHWA, Washington, D.C., November 1978.

Bureau of Motor Carrier Safety. "Accidents of Motor Carriers of Property, 1978," FHWA, Washington, D.C., May 1980.

Bureau of Motor Carrier Safety. "1976-1978 Analysis of Motor Carrier Accidents Involving Vehicle Defects or Mechanical Failure," FHWA, Washington, D.C., November 1979.

Bureau of Motor Carrier Safety. "Commercial Vehicles in Collisions Involving Vehicles Parked or Stopped on Highway Shoulders," FHWA, Washington, D.C., 1977.

Bureau of Motor Carrier Safety. 1975-1979 Data from BMCS File, FHWA, Washington, D.C.

Bureau of Motor Carrier Safety. "Safety Comparison of Doubles vs. Tractor-Semitrailer Operation," FHWA, Washington, D.C., November 1977.

Burger, W.J.; Smith, R.L.; Ziedman, K.; Mulholland, M.D.; Bardales, M.C.; and Sharkey, T.J., "Improved Commercial Vehicle Conspicuity and Signalling Systems," Task I - Interim Report, Report No. VR 80-3, Vector Research, Santa Monica, California, March 1981.

California Highway Patrol. "Recommendations on Federal Mobilehome Transportation Regulations," Commercial and Technical Services Section, Sacramento, California, March 1981.

Campbell, K.L. and Carsten O., "Fleet Accident Evaluation of FMVSS 121," UM-HSRI-81-9, Highway Safety Research Institute, Ann Arbor, Michigan, March 1981.

Cassidy, M.E., "Heavy Trucks: Fatal Accident Reporting System, Special Report," DOT-HS-803-259, National Center for Statistics and Analysis, NHTSA, Washington, D.C., May 1978.

Chatfield, B.V., "Severity of Truck Accidents," Office of Highway Safety, FHWA, Washington, D.C., December 1976.

Chow, G., "The Economics of the Motor Freight Industries," School of Business, Indiana University, Bloomington, Indiana, 1978.

Cirillo, J.A. et al., "Interstate System Accident Reseach Study - 1," FHWA, Washington, D.C., October 1970.

Cirillo, J.A. et al., "Analysis and Modeling of Relationships Between Accidents and the Geometric and Traffic Characteristics of the Interstate System," FHWA, Washington, D.C., August 1969.

Commonwealth of Kentucky. "Problem Identification for Highway Safety Plan (FY'82)," Research Report, UKTP-81-5, Department of Transportation, May 1980.

Council of State Governments. "Driver License Compact," 1961.

Crancer, A., Jr. and McMurray, L., "Accident and Violation Rates of Washington's Medically Restricted Drivers," Journal of the American Medical Association, 200:272-276, July 29, 1968.

Deleys, N.J. and Ryder, M.O., "Underride/Override of Automobile Front Structures in Intervehicular Collision, Volume 1-Heavy Vehicle Rear Underride," DOT-HS-800-626, NHTSA, Washington, D.C., December 1971.

Dynamic Science, Inc. (DSI). "Test and Evaluation of Heavy Vehicle Barrier System," FHWA Contract No. DOT-FH-11-9115, Phoenix, Arizona, December 1981.

Eck, R.W., "Development of Warrants for the Use and Location of Truck Escape Ramps, Volume I-Final Report; Volume II -Appendices," West Virginia DOH 57, Department of Civil Engineering, West Virginia University, Morgantown, West Virginia, February 1980.

Edwards, M., "Develop Knowledge and Performance Tests for Licensing Heavy Vehicle Operators," NHTSA Contract No. DTNH-22-80-C-07336, National Public Services Research Institute, Alexandria, Virginia, August 1980 - September 1983.

Engineering Standards Unit. "Operational Characteristics of 100-Foot Double Trailer/Tractor Combinations in Michigan, Final Report," TSD-279-76, Traffic and Safety Division, Michigan Department of State Highways and Transportation, Lansing, Michigan, December 1976.

Erickson, R.C., Jr., "A History of Truck Escape Ramps in Colorado," Colorado Department of Highways, Presentation at 20th Annual Joint Meeting, Intermountain and Colorado-Wyoming Section of Institute of Transportation Engineers, Jackson, Wyoming, May 16-17, 1980.

Ervin, R.D.; Mallikarjunarao, C.; and Gillespie, T.D., "Future Configuration of Tank Vehicles Hauling Flammable Liquids in Michigan," UM-HSRI-80-73, Highway Safety Research Institute, Ann Arbor, Michigan, December 1980.

Ervin, R.D., "Unintended Responses of Heavy Trucks to Braking or Steering Inputs," The HSRI Research Review, Vol. 10, No. 5, March-April 1980, pp. 1-11.

Fancher, P.S. et al., "Retarders for Heavy Vehicles: Evaluation of Performance Characteristics and In-Service Costs," February 1981.

Fatal Accident Reporting System (FARS). 1976-1981 Data from FARS File, National Center for Statistics and Analysis, NHTSA, Washington, D.C.

Fatal Accident Reporting System (FARS). "Traffic Fatal Accident and Fatality Data Collected in FARS for the Year 1980," DOT-HS-805-953, National Center for Statistics and Analysis, NHTSA, Washington, D.C., October 1981.

Federal Highway Administration. "Fatal and Injury Accident Rates on Federal-Aid and Other Highway Systems/1979," Washington, D.C., May 1981.

Federal Highway Administration. "Highway Statistics," for the years 1970-1980, Washington, D.C.

Federal Highway Administration. "Federal Highway Cost Allocation Study, Final Report," Washington, D.C., May 1982.

Federal Highway Administration. Memorandum from Highway Statistics Division on VMT Estimates, Washington, D.C., May 1982.

Federal Highway Administration. "Review of Safety and Economic Aspects of Increased Vehicle Sizes and Weights," Washington, D.C., September 1969.

Federally Coordinated Program (FCP) of Research and Development, Project 1T, Advanced Vehicle Protection Systems, FHWA, Washington, D.C., 1981.

Ferris, R.; Malone, T.B.; and Lilliefors, H., "A Comparison of Alcohol Involvement in Exposed and Injured Drivers, Phases I and II," DOT-HS-801-826, NHTSA, Washington, D.C., February 1976.

Florida Department of Transportation. "Impact of State Highways on Tractor-Trailers Hauling Loads Wider Than Twelve Feet," September 1972.

Galligan, J., "The Hunt for Better MPG," Commercial Car Journal, Volume 138, Number 9, September 1981.

Glauz, W.D.; Hutchison, B.M.; and Kobett, D.R., "Economic Evaluation of Mobile and Modular Housing Shipments by Highway, Volume I-Research Report; Volume II-Appendices," FHWA-RD-74-63,64, FHWA, Washington, D.C., April 1974.

Glennon, J., "Matched Pair Analysis," for Consolidated Freightways, c. 1979 mimeo.

Gordon, D.A., "Highway Sight-Distance Requirements: Truck Applications," Final Report, FHWA-RD-79-26, Office of Research, FHWA, Washington, D.C., February 1979.

Green, P.; Kubacki, M.; Olson, P.L.; and Sivak, M., "Accidents and the Nighttime Conspicuity of Trucks," UM-HSRI-79-92, Highway Safety Research Institute, Ann Arbor, Michigan, January 1980.

Hackman, K., "An Analysis of the Problem of Multiple Licenses and Multiple Records," NHTSA Contract No. DTNH-22-80-C-07032, National Institute for Safety Research, Rockville, Maryland, November 1979 - December 1981.

Hackman, K.D.; Larson, E.E.; and Shinder, A.E., "Analysis of Accident Data and Hours of Service of Interstate Commercial Motor Vehicle Drivers," Final Report, Genasys Corporation, Rockville, Maryland, and Safety Management Institute, Bethesda, Maryland, August 1978.

Harris, W. and Mackie, R.R., "A Study of the Relationships Among Fatigue, Hours of Service, and Safety of Operations of Truck and Bus Drivers, Final Report--Phases I and II," 1727-2, Human Factors Research, Inc., Goleta, California, November 1972.

Hedlund, J., "The Severity of Large Truck Accidents," DOT-HS-802-332, NHTSA, Washington, D.C., April 1977.

Herzog, T.N., "Injury Rate As A Function of Truck Weights in Car-Truck Accidents," DOT-HS-801-472, NHTSA, Washington, D.C., June 1975.

Highway Cost Allocation Study, (HCAS). Data from the 1977 Truck Inventory and Use Survey Adjusted to Reflect Polk Totals by the FHWA Cost Allocation Study, Office of Program and Policy Planning, FHWA, Washington, D.C., (see p. C-8 for explanation of data differences).

Janke, M.K.; Peck, R.C.; and Dreyer, D.R., "Medically Impaired Drivers: An Evaluation of California Policy," Final Report to the Legislature of the State of California, (Report CAL-DMV-RSS-78-67), Research and Development Section, Division of Drivers Licenses, September 1978.

Kimball, C.E.; Bronstad, M.E.; Michie, J.A.; Wentworth, J.A.; and Viner, J.G., "Development of a Collapsing Ring Bridge Railing System," FHWA-RD-76-39, FHWA, Washington, D.C., January 1976.

King, G.F.; Abramson, P.; and Duerk, C., "Truck Blockage of Signals," Transportation Research Record #597, 1976, pp. 1-9.

Knoblauch, R.L. and Tobey, H.N., "Safety Aspects of Using Vehicle Hazard Warning Lights, Volume I: Executive Summary; Volume II: Research Report," FHWA-RD-80-101, 102, FHWA, Washington, D.C., June 1980.

Kubacki, M. and O'Day, J., "The Effect of Cab Style on the Accident Experience of Heavy Trucks," UM-HSRI-81-03, Highway Safety Research Institute, Ann Arbor, Michigan, February 1981.

Labra, J.J., "Impact Attenuators for Heavy Vehicles - A Feasibility Study, Phase I, Final Report," FHWA Contract No. FH-11-9342, Southwest Research Institute, San Antonio, Texas, October 1979.

Li, L.K.; Dunham J.R.; Waller, P.F.; and Leggett, E., "Truck Drivers: Licensing and Monitoring an Analysis With Recommendations, Appendix Volume A: Summary of Literature Review," Final Report, Highway Safety Research Center, Chapel Hill, North Carolina, December 1979.

Lill, Richard A., "Review of BMCS Analysis and Summary of Accident Investigations, 1973-1976 with Respect to Downgrade Runaway Type Accidents," American Trucking Associations, Inc., Memorandum, September 13, 1977.

Little, A.D., Inc. "The Safety of High Gross Weight Trucks," for Massachusetts Construction Industry Council, March 1974.

Lohman, L.S.S. and Waller, P., "Trucks: An Analysis of Accident Characteristics by Vehicle Weight," Highway Safety Research Center, Chapel Hill, North Carolina, September 1975.

Lum, H.S., "Evaluation of Techniques for Warning of Slow-Moving Vehicles Ahead: Executive Summary," FHWA-RD-79-97, FHWA, Washington, D.C., July 1979.

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

Mackie, R.R.; O'Hanlon, J.F.; and McCauley, M., "A Study of Heat, Noise, and Vibration in Relation to Driver Performance and Physiological Status," DOT-HS-801-315, NHTSA, Washington, D.C., December 1974.

Maister, D.H., Management of Owner-Operator Fleets, Lexington Books, Lexington, Massachusetts, 1980.

McBride, R. and Jones, B., "Driver License Compact Study," The Council of Governments, Lexington, Kentucky, 1981.

McDole, T.L. and O'Day, J., "Effects of Commercial Vehicle Systematic Preventive Maintenance on Specific Causes of Accidents," UM-HSRI-SA-75-13, Highway Safety Research Institute, Ann Arbor, Michigan, July 1975.

McGee, H.W., "Synthesis of Large Truck Safety Research," Final Report, DTNH22-81-P-07359, NHTSA, Washington, D.C., July 1981.

Meyers, T.T.; Ashkenas, I.L.; and Johnson, W.A., "Feasibility of a Grade Severity Rating Systen," FHWA-RD-79-116, FHWA, Washington, D.C., August 1980.

Minahan, D.J. and O'Day, J., "Car-Truck Fatal Accidents in Michigan and Texas," UM-HSRI-77-49, Highway Safety Research Institute, Ann Arbor, Michigan, October 1977.

Moe, G.L.; Kelley, G.R.; and Farlow, D.E., "Truck and Bus Driver Task Analysis," Human Factors Research, Inc., Goleta, California, May 1973.

Moffatt, C.A.; Wong, J.; and Zaremba, L.A., "Improved Underride Protection in Moderate Speed Crashes," Proceedings, 24th Conference of the American Association of Automotove Medicine, October 7-9, 1980, pp. 257-272.

Motor and Equipment Manufacturer's Association. "Survey Pinpoints Ways Trucking Firms' Owner-Operators' Vary in Making Major Purchases," Transport Topics, May 14, 1979, p. 66.

Najjar, D., "A Comprehensive Approach to Truck Accident Data," National Center for Statistics and Analysis (unpublished paper), NHTSA, Washington, D.C., August 1981.

National Accident Sampling System (NASS). 1979-1980 Data from NASS File, National Center for Statistics and Analysis, NHTSA, Washington, D.C.

National Accident Sampling System (NASS). "Report on Traffic Accidents and Injuries for 1979-1980," DOT-HS-806-176, National Center for Statistics and Analysis, NHTSA, Washington, D.C., February 1981.

National Committee on Uniform Traffic Laws and Ordinances (NCUTLO). "Uniform Vehicle Code and Model Traffic Ordinances," Washington, D.C., 1979.

National Highway Traffic Safety Administration. "Heavy Truck Safety Meeting--Summary of Comments," Washington, D.C., September 10-11, 1979.

National Highway Traffic Safety Administration. "The National Driver Register: A Part of the State Driver Licensing System - A Report to Congress," Washington, D.C., June 1980.

National Public Services Research Institute (NPSRI). "Preparation of a Tractor-Trailer Driver Training Standards and a Model Curriculum," FHWA Contract No. DTFH61-80-C-00037, Alexandria, Virginia, March 1980 - January 1982.

National Transportation Safety Board (NTSB). "Safety Effectiveness Evaluation of Detection and Control of Unsafe Interstate Commercial Drivers Through: The National Driver Register - State Driver Licensing Policies - The Federal Motor Carrier Safety Regulations," NTSB-SEE-80-1, Washington, D.C., February 1980.

Naughton, T.J., Jr. and Waller, J., "Feasibility of Developing a Medical Condition Data Collection System for Driver Licensing," NHTSA Contract No. DOT-HS-7-01796, Dunlap and Associates, Inc., Darien, Connecticut, February 1980.

Northrop, G.M.; Reidy, J.C.; and Costenoble, K.C., "An Analysis of Commercial Motor Vehicle Accidents in Commercial Zones," CEM 4176-546, The Center for the Environment and Man, Inc., Hartford, Connecticut, April 1976.

O'Brien, J.F., "Cardiovascular Disease and Motor Vehicle Accidents," State of New York Department of Motor Vehicles, May 1979.

O'Day, J.; Filkins, L.; and Kaplan, R., "Combination Vehicles: Five-Year Accident Experience," UM-HSRI-80-51, Highway Safety Research Institute, Ann Arbor, Michigan, July 1980.

Oregon Senate Interim Task Force. "Regulation of the Motor Carrier Industry," State of Oregon.

Partyka, S.C., "An Analysis of Available Data for Car-to-Heavy Truck Accidents and the Underride Problem," National Center for Statistics and Analysis, NHTSA, Washington, D.C., June 1979.

Partyka, S.C., "Heavy Truck Report to Congress Working Group Papers, Number 1 through 8," National Center for Statistics and Analysis (unpublished papers), NHTSA, Washington, D.C., June-September 1981.

Partyka, S.C., "Truck Type Classification," National Center for Statistics and Analysis (unpublished paper), NHTSA, Washington, D.C., May 1981.

Peterson, D.E. and Gull, R., "Triple Trailer Evaluation in Utah," UDOT-MR-75-4, Utah Department of Transportation, Research and Development Section, Salt Lake City, Utah, September 1975.

Philipson, L.L.; Rashti, P.; and Fleischer, G.A., "Statistical Analyses of Commercial Vehicle Accident Factors, Volume I--Technical Report, Part I," DOT-HS-803-418, NHTSA, Washington, D.C., February 1978.

Post, E.R.; Hirsch, T.J.; and Nixon, J.F., "Truck Tests on Texas Concrete Median Barrier," Highway Research Record #460, 1973, pp. 73-81.

Radlinski, R.W., "Air Braked Vehicle Performance: FMVSS No. 121 Braking Systems Versus Pre-FMVSS No. 121 Braking Systems and Stability Augmentation Devices," DOT-HS-801-967, NHTSA, Washington, D.C., August 1976.

Radlinski, R.W., "NHTSA Air Brake Research Program, 1979-1981," Draft Report, NHTSA, Washington, D.C., March 1982.

Radwan, A.E.S., "Characteristics of Heavy Truck Accidents," JHRP-76-18, Joint Highway Research Project, Engineering Experiment Station, Purdue University, West Lafayette, Indiana, June 1976.

Radwan, A.E.S. and Sinha, K.C., "Effect of the National Speed Limit on the Severity of Heavy Truck Accidents," Traffic Quarterly, Vol. 32, No. 2, April 1978, pp. 319-328.

Ramsett, D. and Sherrer, R.W., "The Demand for Small Cars and the Resulting Automobile Fleets 1970-1990," Small Car Safety in the 1980's, DOT-HS-805-729, NHTSA, Washington, D.C., March 1981.

Raven Systems and Research, Inc. "Review of Studies of the Relationship Between Motor Carrier Economic Regulation and Highway Safety," DOT-OS-90048, U.S. Department of Transportation, Washington, D.C., October 1979.

Raven Systems and Research, Inc. "The Relationship Between Motor Carrier Regulation and Highway Safety," DOT-OS-90048, U.S. Department of Transportation, Washington, D.C., March 1981.

Reiss, M.L., "Analysis of Age, Experience, Licensing Status, and Accident/Violation Records of Drivers of Heavy Vehicles Phase I: Feasibility Study," NHTSA Contract No. DTNH-22-80-C-07033, National Institute for Safety Research, Rockville, Maryland, September 1980 - November 1982.

Sanders, M.S., "A Nationwide Survey of Truck and Bus Drivers," Canyon Research Group, Inc., Westlake Village, California, March 1977.

Scott, R.E. and O'Day, J., "Statistical Analysis of Truck Accident Involvements," DOT-HS-800-627, NHTSA, Washington, D.C., December 1971.

Shinar, D., "Truck Drivers: Licensing and Monitoring. An Analysis with Recommendations. Appendix Volume D-1: An Analysis of the Causes of Large Truck Accidents, and Volume D-2: An Evaluation of Heavy Vehicle Driver Visual Requirements," Final Report, Highway Safety Research Center, Chapel Hill, North Carolina, December 1979.

Simpson, H.M.; Warren, R.A.; and Page-Valin, L., "Medical Conditions and Risk of Collision; A Feasibility Study," For Canadian Conference of Motor Transport Administrators, Traffic Injury Research Foundation of Canada, Ottawa, Canada, June 7, 1977.

Smist, T.E. and Ranney, T.A., "Heavy Truck Accident Causation," unpublished memorandum report to NHTSA, Calspan Field Services, Inc., August 1981.

Smith, R.A.; Fell, J.C.; Smith, S.R.; and Hart, S.A., "The National Accident Picture--1979," NHTSA, Presentation at American Association for Automotive Medicine 25th Annual Conference, San Francisco, California, October 1-3, 1981.

Solomon, D., "Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle," Bureau of Public Roads, Department of Commerce, Washington, D.C., July 1964.

Terhune, K.W. and Fell, J.C., "The Role of Alcohol, Marijuana, and Other Drugs in the Accidents of Injured Drivers," NHTSA, Presentation at the 25th Annual Conference for American Association for Automotive Medicine, San Francisco, California, October 1981.

Texas Transportation Institute (TTI). "Test and Evaluation of High Performance Median Barriers," FHWA Contract No. DOT-FH-11-9485, College Station, Texas, May 1979 - May 1982.

Texas Transportation Institute (TTI). "Development of Safer Bridge Railing," FHWA Contract No. DOT-FH-11-9181, College Station, Texas, February 1982.

Truck Inventory and Use Survey (TIU). 1977 Data from TIU File, Bureau of Census, Washington, D.C.

Vallette, G.R.; McGee, H.W.; Sanders, J.H.; and Enger, D.J., "The Effect of Truck Size and Weight on Accident Experience and Traffic Operations, Volume III: Accident Experience of Large Trucks," FHWA/RD-80/137, FHWA, Washington, D.C., July 1981.

VanZweden, J. and Bryden, J.E., "In-Service Performance of Highway Barriers," New York State Department of Transportation, Research Report 51, July 1979.

Waller, J.A., "Chronic Medical Conditions and Traffic Safety, Review of California Experience," New England Journal of Medicine, 273:1413-1420, December 23, 1965.

Waller, J.A., "Medical Impairment to Driving," Thomas, Springfield, Illinois, 1973.

Waller, P.F. and Li, L.K., "Truck Drivers: Licensing and Monitoring. An Analysis with Recommendations. Summary Report," Final Report, Highway Safety Research Center, Chapel Hill, North Carolina, December 1979.

Waller, P.F.; Hall, R.G.; Li, L.K.; Padgett, S.S.; and Lowery, H.A., "Classified Licensing: Development of Procedures and Materials. Volume III - Licensing of Operators of Large Trucks and Buses," Highway Safety Research Center, Chapel Hill, North Carolina, December 1976.

Washington State Utilities and Transportation Commission. "Summary and Analysis: Heavy Truck-Hazardous Material Accidents," Olympia, Washington, 1980.

Weir, D.H.; Ringland, R.F.; Heffley, R.K.; and Ashkenas, I.L., "An Experimental and Analytical Investigation of the Effect of Truck-Induced Aerodynamic Disturbances on Passenger Car Control and Performance, Executive Summary Report and Technical Report," FHWA-RD-71-2, 3, FHWA, Washington, D.C., October 1971.

Western Highway Institute. "Motor Vehicle Size and Weight Standards, Western Regional Objectives," A Study for the TRED Foundation, San Bruno, California, July 1980.

Williams, E.C., Jr., "Emergency Escape Ramps for Runaway Heavy Vehicles," FHWA-TS-79-201, Office of Research and Planning, Tennessee Department of Transportation, Nashville, Tennessee, March 1978.

Wilson, L.J. and Horner, T.W., "Data Analysis of Tractor-Trailer Drivers to Assess Drivers' Perception of Heavy Duty Truck Ride Quality," DOT-HS-805-139, NHTSA, Washington, D.C., September 1979.

Wiltshire, D.M., "Truck Driver Training and Motivation," Third Automotive Fuel Economy Research Contractors' Coordination Meeting - Summary Report, DOT-HS-805-875, NHTSA, Washington, D.C., December 1980.

Winfrey, R. et al., "Economics of the Maximum Limits of Motor Vehicle Dimensions and Weights, Volumes 1 and 2," FHWA-RD-73-69, 70, FHWA, Washington, D.C., September 1968.

Winter, P.A., "1974 Brake Performance Levels for Trucks and Passenger Cars," Bureau of Motor Carrier Safety, FHWA, Washington, D.C., 1975.

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

Yoo, C.S.; Reiss, M.L.; and McGee, H.W., "Comparison of California Accident Rates for Single and Double Tractor-Trailer Combination Trucks," FHWA-RD-78-94, FHWA, Washington, D.C., March 1978.

Zaremba, L.A. and Ginsburg, M.J., "The 55 MPH Limits and Front-to-Rear Collisions Involving Autos and Large Trucks," Accident Analysis and Prevention, Volume 9, 1977, pp. 301-314.

Zaremba, L.A.; Wong, J.; and Moffatt, C.A., "Eliminating Automobile Occupant Compartment Penetration in Moderate Speed Truck Rear Underride Crashes: A Crash Test Program," Insurance Institute for Highway Safety, Washington, D.C., April 1977.

Zeiszler, R., "Accident Experience of Double Bottom Trucks in California," Department of California Highway Patrol, April 1973.

Zieszler, R., "A Study of California Truck Accidents," Department of California Highway Patrol, Revised, April 1973.

CONTRIBUTORS TO DOCKET ON TRUCK ACCIDENT CAUSATION

Docket Number		Date of Receipt	Name of Submitter	Date of Document
81-06-N01-		4/23/81	Federal Register, VI. 46, pg. 23184-6	4/23/81
	001	4/17/81	NHTSA - Plans and Programs: Summary Work Plan	4/17/81
	002	5/15/81	Automobile Club of New York, Inc. (AAA)	5/7/81
	003	5/15/81	American Automobile Association (AAA)	5/13/81
	004	5/15/81	Wagner Division, McGraw-Edison Co.	5/18/81
	005	5/18/81	William M. Cessna	5/12/81
	006	5/21/81	Private Truck Council of America, Inc.	5/14/81
	007	5/19/81	The General Tire and Rubber Co.	5/14/81
	008	5/18/81	Roy A. Traster	5/10/81
	009	5/27/81	AAA Foundation for Traffic Safety	5/19/81
	010	5/22/81	Pyrotechnic Signal Manufacturers Association, Inc.	5/22/81
	011	5/27/81	Western Highway Institute	5/18/81
	012	5/27/81	Illinois Department of Transportation	5/14/81
	013	5/26/81	Motor Vehicle Manufacturers Association	5/26/81
	014	5/22/81	National Automobile Dealers Association	5/22/81
	015	5/28/81	Atwood Mobile Products	5/21/81
	016	5/28/81	Truck Trailer Manufacturers Association	5/26/81
	017	5/28/81	State of Minnesota, Department of Public Safety	5/13/81
	018	5/28/81	Ray Cleveland	5/13/81
	019	6/2/81	Philip R. Miller	5/21/81
	020	6/2/81	Fleet Owner	5/21/81
	021	6/2/81	Kansas Department of Transportation	5/27/81
	022	6/3/81	Motor Vehicle Manufacturers Association to NHTSA's Administrator; 4 attachments included	6/1/81
	023	6/11/81	Arthur, Dry and Kalish, P.C.	6/3/81
	024	6/15/81	Washington Utilities & Transportation Commission	6/9/81
	025	6/23/81	National Transportation Safety Board (James B. King)	6/22/81
	026	6/24/81	Breeze Corporation, Inc.	5/11/81
	027	6/24/81	Breeze Corporation, Inc.	6/15/81
	028	7/7/81	Connecticut Construction Industries Association, Inc.	7/1/81
	029	7/13/81	Law offices of William C. Gordon	7/7/81

Number 231, September 1981
ISSN 0097-8515

TRANSPORTATION RESEARCH CIRCULAR

Transportation Research Board, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, DC 20418

TRUCK-ACCIDENT DATA SYSTEMS: STATE-OF-THE-ART REPORT

mode
1 highway transportation

subject areas
51 transportation safety
52 human factors

Steering Committee for Workshop on Truck-Accident Data

Chairman:
James O'Day, Highway Safety Research Institute, University of Michigan, Ann Arbor

Members:
Rodney Harris, Motor Vehicle Manufacturers Association, Detroit
William Johns, Technical Services Division, American Trucking Associations, Washington, D.C.
Livia K. Li, Highway Safety Research Center, University of North Carolina, Chapel Hill
Kenneth A. Thompson, Yellow Freight Lines, Inc., Overland Park, Kansas
Larry Wort, Bureau of Safety Operations, Illinois Department of Transportation, Springfield

TRB Staff Representative:
James K. Williams

Liaison Representatives:
Michael D. Freitas, Office of Research, Federal Highway Administration
H. Douglas Robertson, Systems Development Branch, Accident Investigation Division, National Highway Traffic Safety Administration

Resource Person:
John Law, California Highway Patrol

Proceedings Reporter:
Charlene Semer

CONTENTS

This Transportation Research Circular summarizes the proceedings of the workshop held on May 4-5, 1981, to consider truck safety issues and truck safety data. Among the questions workshop participants addressed were (a) What important issues should guide the collection of truck safety data? (b) What data are now available to help study those issues? (c) How good in quality and how complete are existing data? and (d) What are potential sources of additional data?

The workshop was sponsored by the National Highway Safety Administration (NHTSA) of the U.S. Department of Transportation and was conducted by the Transportation Research Board (TRB). Invited participants were practitioners from enforcement agencies, state highway and transportation agencies, driver organizations, the trucking industry, truck manufacturers, truck insurers, and safety organizations. Each participant has direct practical experience with some aspects of the truck safety problem and is knowledgeable about sources of data on truck accidents. A list of workshop participants and their affiliations is presented in the final section of this report.

Discussion among participants took place mainly in four workshop groups, each of which considered a different facet of truck safety. Each participant was assigned to one of these groups:

1. The overview of truck accidents--characteristics, trends, and forecasts;
2. Highway environment factors in truck accidents;
3. Vehicle factors in truck accidents;
4. Driver factors in truck accidents.

In the final sessions of the meeting, participants met as a whole to hear, discuss, and add to the reports of the four groups. The topical summaries contained in this report represent composites of the group and the plenary discussions in each subject area.

I. BACKGROUND

Heavy-truck accidents are a serious highway safety problem, and many result in fatalities. Data collected through NHTSA's Fatal Accident Reporting System (FARS) indicate a general upward trend in the involvement of heavy trucks in fatal accidents and in the total number and relative proportion of fatalities that result from such accidents.

According to the FARS data, the proportion of all traffic deaths that resulted from heavy-truck accidents increased from 11 percent in 1976 to 13 percent in 1979. Heavy-truck accident fatalities increased 34 percent during this period compared with 12 percent for all traffic accidents. (1980 FARS data show an 11 percent drop in truck-related fatalities.) Passenger-car occupants represent about half of these deaths; a little less than one-fourth are occupants of the heavy trucks; and the remainder are occupants of light trucks or other vehicles, motorcycle riders, and pedestrians.

The increased involvement of heavy trucks in fatal accidents may be due in large measure to an increase in relative exposure in recent years. Car vehicle miles of travel are decreasing, while heavy-truck mileage is either the same or increasing. These trends may be expected to continue. According to William Scott, Director of the NHTSA's National Center for Statistics and Analysis, heavy trucks may be involved in 20 to 25 percent of all fatal highway accidents sometime between 1985 and 1990.

Truck Safety Data Project

The U.S. Senate Committee on Appropriations, concerned about the present and projected involvement of heavy trucks in fatal accidents, has directed the U.S. Secretary of Transportation to learn more about the causes of heavy-truck accidents in order to develop effective countermeasures. NHTSA was assigned the lead role and was instructed to work with a broad cross section of relevant government agencies, industry, and the research community to make a comprehensive analysis of data on truck accidents. The project is to be limited to data on large trucks, which were defined by the Appropriations Committee as those trucks with a gross vehicle weight exceeding 10,000 lb.

Because the project report to Congress is due on January 15, 1982, no new accident data-collection efforts are possible. Nonetheless, a variety of substantive federal and state data sources were utilized in the preparation of this report. These data sources are described here.

1. FARS. Since 1975, NHTSA has collected and aggregated state reports on fatal accidents. These reports include accident cause, vehicle defects, driver drug use, and other variables.

2. Bureau of Motor Carrier Safety (BMCS) Accident Reports. Since 1973, BMCS has required regulated carriers to fill out reports on accidents involving their trucks. The Bureau then aggregates the data furnished in the report. The reports include descriptive data on the vehicle and the highway environment as well as on the accident circumstances and injuries.

3. National Accident Sampling System (NASS). The NASS, which began collecting data in 1979, currently operates a network of 30 traffic accident research teams in selected sites across the country. Researchers study the environmental, vehicular, and human factors associated with a carefully chosen random sample of accidents involving pedestrians, automobiles, motorcycles, bicycles, buses, and trucks. The investigations focus on information such as vehicle crash protection, driver characteristics, roadside hazards, and injury severity. These data are compiled into national totals based on geography, population, and type of roadway.

4. Truck Inventory and Use (TIU) Survey. The TIU is a statistical sample of all trucks registered in the United States. The U.S. Bureau of the Census conducted this survey in 1963, 1967, 1972, and 1977, and will do so again in 1982. Though TIU is not a source of accident data, it does offer exposure data that to some extent match the BMCS data. The TIU data for heavy trucks describe such characteristics as miles traveled, cargo weight, number of trailers, model year, and size of carrier operation.

5. The states also collect data from police accident reports, and some carry out special studies of specific problems. Also, NHTSA Standard 18, promulgated under Section 402 of the Highway Safety Act of 1966, provides for state multidisciplinary accident-investigation teams, which are to follow up specific accidents and provide in-depth reports on them. These reports generally include detailed descriptions of the accident scene, vehicles involved and injuries sustained.

It is certain that other sources of data pertaining to truck accidents exist. Although they would not be national in scope, the statistics that insurers, carriers, safety organizations, safety researchers, and others collect for their own purposes might help NHTSA learn more about the major causes of truck accidents. One of the tasks of the truck safety data project, then, involves unearthing and evaluating these data sources.

The preanalysis phase of the project involves three approaches to discovering existing research and data on truck accidents. All three are proceeding simultaneously. One approach is a comprehensive literature review that will identify research results bearing on heavy-truck accident experience and causation and on the causes of injuries in truck accidents. A contractor, Wagner-McGee Associates, is responsible for this activity. A second approach is a review by NHTSA of existing truck accident and exposure data bases that federal agencies, state transportation or highway departments, insurance companies, and the trucking industry have developed. The workshop, held May 4-5, 1981, is the third element of the data-discovery phase of the truck safety data project.

An interagency coordinating committee, composed of representatives from NHTSA and the Federal Highway Administration (FHWA), is directing this project. The committee has three responsibilities: to coordinate project activities, to provide technical expertise about and access to information about truck safety, and to review the project's progress and output. A working group of several committee members carries out the committee's day-to-day activities.

Scope of Workshop Deliberations

In the workshop's opening session, NHTSA officials explained how NHTSA and FHWA are developing the report to the Senate, what the workshop is expected to contribute to the project, and where the boundaries of the workshop's discussions should lie.

NHTSA Administrator, Raymond A. Peck, Jr., asked the workshop participants to accomplish three tasks:

1. To identify major issues concerning truck safety,
2. To suggest existing sources of data bearing on those issues, and
3. To evaluate the validity and adequacy of that data.

Peck stressed that the project's time constraint does not permit the development of new data sources, even though many gaps exist in our knowledge about truck accidents. However, Peck asked workshop participants to help identify these deficiencies and to suggest sources of existing data that NHTSA might not otherwise know about.

Douglas Robertson, Chief of the Systems Development Branch of NHTSA's Accident Investigation Division and project manager for the truck safety study, detailed NHTSA's organization and plans for the study and the workshop's role in it. He suggested that a first order of business for the workshop should be to identify major issues in truck safety. Then, participants should identify and evaluate sources of data that might shed light on those issues.

The workshop participants were divided into four groups. The overview group was to deal with descriptive data on truck accidents. The other three groups were to concern themselves with causal factors that might lie in highway design and conditions, in the trucks themselves and the way they are operated, and in the drivers and their driving practices. The remainder of this report is based on the deliberations of these four groups.

II. OVERVIEW OF TRUCK ACCIDENTS

James O'Day, chairman;	Sue Partyka, recorder
W.K. Barton	Edward E. Kynaston
Carmen Campbell	John Law
Russ Fiste	Ronald D. Lipps
John F. Harrison	Dan Najjar
Alan F. Hoskin	John A. Pachuta
William Johns	Thomas A. Ranney
Farrel L. Krall	Linda D. Zenker

Several state and federal systems compile data on truck accidents. The federal data present an aggregate view of changes in truck accidents over time. The state data are more detailed than the national data and, hence, are more likely to shed some light on causation. Both types of data have some limitations.

Truck-Accident Data Issues

Two general concerns with respect to existing data are their lack of detail on truck characteristics and the improper interpretation of data that do exist.

Truck Characteristics. Although the distinction between heavy trucks--those weighing more than 10,000 lb.--and pickups and vans is important, it is also important for accident analysis to distinguish among different types of heavy trucks. Truck safety may well differ among trucks according to their size, weight, use, configuration, and other characteristics. Dimensions significant in any comparison of heavy-truck accident rates include cab style (cabover versus conventional), body type (box, flatbed, tanker, other), total length and width, number of trailers, straight trucks versus combinations, and perhaps the types of cargoes carried.

The FARS data distinguish only between straight trucks and combinations and among several broad weight classes. The BMCS data identify trucks, tractors, and trailers, but they do not indicate cab style and usually do not include the vehicle identification number. The identification number of trucks may be of limited value in tracing vehicle characteristics, however, because many trucks undergo major modification (e.g., new bodies or additional axles) after leaving the factory.

State accident reports vary in the amount of truck-characteristic detail they compile and in their definitions of heavy trucks. California, for example, defines large trucks as those with three or more axles. Maryland assigns different license plate numbers to four categories of heavy trucks and thus could retrieve some information about body style and other characteristics. Such inconsistencies among state data preclude aggregating them to produce detailed national statistics by type of truck. Ideally, police agencies should have a common set of truck codes for designating size, weight, model, and other truck characteristics in their accident reports.

Interpretation of Data. Proper presentation, interpretation, and use of the truck accident data that are collected are matters for some concern. For example, accident rates that are reported without reference to actual numbers can be misleading. For sampled data, such as that gathered through NASS, variance is also important. Variance is less critical for census-type data, such as FARS collects. Some analysts argue, however, that because one or two years of time-series data may be viewed as a sample of the whole set, analysts should compute statistical bounds for short-term data, just as for any other sample.

Collection and use of data that have inherent limitations constitute another interpretation problem. For example, the "out-of-service" statistics that FHWA collects on trucks that do not pass inspection are influenced by the practice of choosing to inspect those trucks that appear most likely to fail. Such data may be of value, but analysts should take selectivity into consideration and should qualify their interpretations accordingly.

In order to minimize statistical misinterpretation, analyses of truck accident data should include a full discussion of possible errors and uncertainties in the data. Results should be presented in the scientific literature or in forums such as those TRB provides. Such arrangements for peer review would permit the challenging of results that are not properly supported.

National Data Bases

A limitation of all national data on truck accidents, for purposes of meeting NHTSA's congressional mandate, is that they are more useful for tracking accident rates over time than for suggesting useful countermeasures for truck accidents. Another limitation is that these data systems are only as reliable as the reports that are fed into them, and many such reports are inconsistent with one another, limited in coverage, or possibly inaccurate.

FARS. The FARS is generally accepted as the most complete data base for fatal accidents. The present file structure permits a variety of analyses not possible a few years ago, but it cannot identify truck characteristics such as body style, configuration, cargo, or weight. FARS depends on state reporting, but all states do not necessarily report on all variables, and categories and definitions also vary among the states.

BMCS Accident Reports. The BMCS data base carries a commendable level of detail about accidents that meet certain criteria, but it does not include all truck-involved accidents. Because the BMCS data include primarily regulated, interstate carriers, they cannot be considered to represent the total population of trucks weighing more than 10,000 lb.

The ability of the BMCS data to help establish causality may be limited to some degree by their dependence on carrier self-reporting. Carriers may not know some specifics about their trucks at the time of an accident. It is unlikely that safety violations are fully reported. BMCS does issue follow-up questionnaires to subsets of the accident population, and these allow further study of specific problems.

During the next six months BMCS expects to modify its truck accident report form to include new causation categories. The modified forms may produce data useful for within-file analysis that will help identify problems and evaluate programs.

NASS. In 1979, the NASS program was operating at only a fraction of the level planned for it. Of the projected 75 accident investigation teams, 10 were in operation, and they collected data on about 300 heavy-truck accidents. These numbers are increasing. At present, there are 30 teams in operation. Eventually this data base will be capable of producing a representative sample of police-reported truck accident data in considerable detail. These data should permit analysis of truck accident characteristics.

TIU. The 1977 TIU exposure data on trucks do not completely match the BMCS data on accidents. For example, TIU reports the usual or typical gross vehicle weights for a particular truck, whereas BMCS data are based on the actual weight of a vehicle at the time of an accident. The 1982 TIU survey will report empty, typical, and maximum weights for each truck, which should improve the accuracy of accident rates computed by combining TIU and BMCS data. Of course, uncertainties about the reliability of reporting under either system will still remain.

State Data

State accident data generally do not use a common threshhold for reporting accidents and thus do not lend themselves to aggregation on a national basis. Nevertheless, state data could be useful in problem identification. Most heavy-truck accidents occur in the several large states that have considerable heavy-truck populations, and aggregated truck accident data from those states would probably adequately represent the characteristics of most heavy-truck accidents.

Many state reports include a level of detail on specific types of accidents, not now collected on a nationwide basis, that could be useful in analyzing causes of those particular accidents. For example, mountainous states may specifically identify downhill runaways, whereas this event is not common enough in all states to reach the FARS file. States also collect data on nonfatal accidents, which the FARS file would not include.

A limitation of state data bases is that they are gathered from police reports, which in turn depend partly on drivers' statements. Drivers may not know the answers to some specific questions or may be reluctant to admit violations or noncompliance with regulations. This could result in underestimating causality associated with certain factors.

State Bilevel Studies. Many states conduct bilevel studies in conjunction with their normal police accident-reporting programs. California, for example, has collected such supplementary reports in connection with truck accidents, and Colorado has collected supplementary reports for downhill runaways.

State MDAI Team Reports. The number of heavy-truck accident reports completed by federally sponsored multidisciplinary accident investigation (MDAI) teams is relatively small, although some (South Carolina, for example) may have carried out several such investigations. These reports include such details as cause and type of occupant injury and details of crash damage. Many of these reports follow the format developed for federal MDAI studies and thus could probably be aggregated.

Other State Data. Most states have conducted specific studies of highway accident problems for use within their own jurisdictions. (For example, see R. Zeiszler, Accident Experience in Double Bottom Trucks in California, Department of California Highway Patrol, April 1973.) Many were published privately in limited quantities, however, and so are not generally available. A survey of state highway departments to discover the existence of such studies might yield substantial amounts of information about truck accidents.

Several states (some in conjunction with BMCS) have truck inspection teams that have collected information on the physical condition of trucks. California, for example, has compiled statistics on vehicle condition, including a relatively detailed examination of braking systems.

III. HIGHWAY ENVIRONMENT FACTORS

Larry Wort, chairman; Hugh McGee, recorder
Charles N. Brady — David J. Hensing
Raymond R. Crowe — R.P. Smith
Michael D. Freitas — Paul Stalknecht
Carl Hayden

Truck weight and type are significant determinants of the extent to which the highway environment contributes to truck accidents. This is because different trucks may respond differently under the same highway conditions. In order to understand these differences, accident data should be separately identified by truck characteristics. At least two weight groups would be appropriate: 10,000 to 26,000 lb. and more than 26,000 lb. Truck type is also important. Combinations account for 90 percent of the heavy trucks involved in fatal accidents, and NHTSA's study should separately identify and emphasize these vehicles. Individual states have developed exposure data (vehicle miles of travel) for combination trucks, which could be used to calculate and examine accident rates specifically for those trucks.

Data that NHTSA could use to relate truck accidents to highway deficiences or to highway design are generally lacking. It is probable that highway design standards, such as those for geometrics, pavement structure, stopping-sight distances, and acceleration-deceleration lanes, do affect truck safety, albeit indirectly. Existing data bases do not permit analysis of the relationship of these standards to truck accidents, however.

Highway type may also be a significant contributory factor in truck accidents. For example, in Illinois, interstate travelway routes--highways that are used during construction of an interstate route--have much higher truck accident rates than do other interstate routes, but no data have been collected to help explain this difference.

Highway appurtenances, such as New Jersey barriers, guard rails, and crash cushions, are important factors in the severity of truck accidents. Although additional data are necessary to develop design improvements, some engineering data exist now, and additional pertinent information is being developed. (For example, see C.E. Kimball, M.E. Bronstad, J.A. Michie, J.A. Wentworth, and J.G. Viner, Development of a Collapsing Ring Bridge Railing System, Southwest Research Institute, FHWA-RD-76-39, January 1976.) The present design of New Jersey barriers may afford more protection to cars than to trucks, but new barrier designs are being tested and these may prove satisfactory for trucks. FHWA has already developed a guardrail standard that adequately protects both cars and trucks, but the cost of such rails in prohibitive for many states. More engineering data are needed to discover whether crash cushions now in use absorb enough energy to reduce adequately the severity of accidents involving very heavy vehicles.

Maintenance and construction areas on highways are problems for trucks, particularly the "S" curves at median crossovers and short detours. FHWA standards address this problem, and uniform application and enforcement of those standards should reduce truck accidents at these points. Data are lacking that would indicate the extent to which drop-offs at the edges of paved highways, which are sometimes severe during construction, are a serious cause of truck accidents.

Several specific types of truck accidents, though not necessarily directly caused by highway conditions, may be influenced by the highway environment. In such cases, highway modifications and improvements might reduce the likelihood that other, nonhighway factors will cause accidents. For example, speed plus large size in trucks may be directly associated with rollover accidents on freeway ramps; nevertheless, changes in ramp design might help reduce the probability that a heavy truck, going too fast, will roll over.

Some engineering data are available on the freeway rollover problem. We know, for instance, that combination trucks roll over with lower "g" forces than automobiles (R.D. Ervin, The Dynamic Stability of Fuel-Carrying Double-Tanker Trucks in Michigan, Highway Safety Research Institute, June 1978). Computerized data on the specifics of actual rollover accidents on ramps are not available, however. Sufficient data of this type exist at the state level, which, if collected and combined, might provide a basis for determining relationships among ramp configuration, speed, truck weight, and other factors.

Several special studies exist that also might include some data on ramp accidents. Studies that Dynamic Science conducted for BMCS probably include some data on rollover accidents on ramps (R.L. Anderson, R.A. Nicky, G. McCormick, and F. Russoniello, Control of Large Commercial Vehicle Accidents Caused by Front Tire Failures, Dyn Sci-2320-75-130, Dynamic Science Division, Ultrasystems, Inc., Phoenix, AZ, August 1975). FHWA studied about 10,000 accidents during a 10-year period on 8,000 to 9,000 miles of the Interstate system in 16 states, which might include quantitative data on rollovers on ramps and permit calculation of rollover frequency as a function of curvature and length of ramp (J.A. Fee (nee Cirillo), R.L. Beatty, S.K. Dietz, D.F. Kaufman, and J.G. Yates, Interstate System Accident Research Study-1, U.S. Department of Transportation, FHWA, October 1970).

The highway environment also influences jackknife accidents. Highways with tight curves and pavements with low skid resistance contribute to such accidents. Unsafe maneuvers, such as high speed or sudden changes in speed, can lead to jackknifing. Data showing the relationships among truck characteristics, driving practices, highway conditions, and jackknifing may exist, but they apparently have not been collected and analyzed.

A frequent type of truck-involved accident is the collision of cars into truck rear ends. These accidents happen most often in the traveled lanes of highways, but they also occur in other locations such as on highshoulders or in climbing lanes. Existing data are probably sufficient to support analysis of why these car-truck rear-end accidents happen.

IV. VEHICLE CHARACTERISTICS AND OPERATION

Rodney Harris, chairman; Robert Clarke, recorder
Gerry Davis — Jame O'Steen
Claude Harris — Donald W. Vierimaa
Farrel L. Krall — Wallace E. Whitmer
William W. Neuman

Like the highway environment, vehicle-related factors are rarely cited as direct causes of truck accidents. Nevertheless, the maintenance, operation, and design of vehicles and the way the vehicles and drivers interact are important to accident avoidance and to mitigation of injury should a crash occur.

Vehicle Safety Factors

Vehicle-related factors that might contribute to heavy-truck accidents and that should be a focus for further study include:

1. Improper maintenance of brakes, tires, lighting systems, handling and stability systems (suspension, tire inflation, etc.), and steering systems;
2. Improper operation, such as excessive speed or splash and spray, poor loading practices, and exceeding the performance capabilities of a specific vehicle;
3. Poor driver visibility, both of the road and of controls, and cab environmental factors; and
4. Design elements (e.g. size, weight, and configuration of the truck), brake performance and maintainability, and tire traction, wear properties, and load sensitivity.

Design factors that may help mitigate the severity of injury to the driver in a crash would include the use of seat belts for the driver, windshields and doors to help prevent ejection, rollover crush protection for the driver, coupling system integrity, proper load retention, and fuel systems that will minimize postcrash fire potential.

It may be possible to demonstrate in laboratory or test environments the relationships between safety and vehicle design, but in practice, it is difficult to separate vehicle design from driving practices, highway environment, and other factors in accident causation. National data bases, such as FARS or BMCS, lack the detail to demonstrate what changes in vehicle design might reduce the likelihood of accidents or help avoid serious injuries or fatalities. In-depth accident investigation may provide sufficiently detailed data about a few accidents, but these few may not be nationally representative and findings based on them could not be generalized to the whole truck population.

Because of the limitations of any one of the existing data-collection systems, it may be necessary to combine accident and exposure data, engineering tests, and field evaluation results in order to make sound decisions about countermeasures that involve vehicle characteristics.

Economic and Regulatory Influences on Vehicle Design

State statutes limit overall vehicle length, width, height, and total and individual axle weights. Certain truck design features reflect attempts to maximize the revenue-generating capability of trucks within size and weight constraints. It is possible that some of these features might have concomitant safety consequences, but data to support causal judgments are lacking.

For example, the cab-over-engine truck tractor allows more length to be devoted to the trailer, thus increasing cargo space. It may offer other advantages as well—easier maintenance, better driver visibility, and greater maneuverability. It has been claimed, however, that this design is less comfortable for drivers and offers them less crash protection than a conventional cab-behind-engine design, but data are not available to support or refute this claim.

Low vehicle tare weight is also desirable in order to maximize cargo weight within state-imposed weight limits. This consideration, along with cost, must be considered in the decision to add certain safety devices to trucks. If a designer contemplates adding a safety device, such as a rear underride protection system, to a truck, the designer must consider whether the potential safety benefits of the device are sufficiently great to offset adverse cost, weight, or operational consequences. Thus, unless such devices have proven safety effectiveness, designers may be reluctant to incorporate them into new truck designs.

Truck width also affects safety, and in the United States width is generally limited to 96 in. This limitation constrains cargo-carrying capacity, and pressures exist in the United States to increase this standard. Proponents point out that Canada allows 102-in. truck widths and that increased width could reduce a truck's rollover threshhold and increase its lateral dynamic stability. The safety consequences of occupying more road space are unknown, however. Perhaps Canadian data on the net safety cost or benefit or increasing truck widths could be examined.

V. DRIVER CHARACTERISTICS AND PRACTICES

Livia Li, chairman; Charles Overbey, recorder

Tom Bailey	A. James McKnight
Theodore E. Brooks	Martin L. Reiss
B.E. Chisolm, Jr.	Warren J. Rheaume
Robert T. Hindle	Kenneth A. Thompson

The role of the driver in heavy-truck accidents is particularly difficult to assess. There is no easy way to trace a specific driver's record of accidents and violations from one state to another. There is also no easy way to determine a driver's physical and psychological status at the time of an accident. Exposure data are also lacking.

Driver Issues

Several driver characteristics appear significant in heavy-truck accidents. Age and driving experience, for example, are important correlates of such accidents. Because young drivers and inexperienced drivers have higher accident rates than do others, some carriers set minimum age and experience requirements in hiring drivers. A problem in analyzing the causal significance of these two variables in heavy-truck accidents, however, is that age and experience are highly correlated. The causal relationship of age to accidents and experience to accidents may be quite different in nature, but it would be difficult to assess them separately.

An additional problem is that good information on driving experience is hard to obtain. Although driver age is routinely reported on most accident forms, driver experience may or may not be reported. Even if experience is recorded, its definition is elusive. "Experience" may refer to years with a particular carrier or to years of driving a particular truck. NHTSA has an ongoing project that addresses this problem (See Analysis of Age, Experience, Licensing Status, and Accident/Violations of Drivers of Heavy Vehicles, DTNH 22-80-C-00733. This project is being carried out by the National Institute for Safety Research, Inc., Rockville, MD).

Driver training, as distinguished from experience, is also a likely factor in heavy-truck accidents, but it is one about which little is known. Some trucking companies have training programs for their drivers, but many drivers acquire their training through commercial schools, through apprenticeship with an experienced driver, or through self-teaching behind the wheel. Acting on the supposition that training is indeed an important safety factor, BMCS is attempting to improve heavy-truck driver training by developing a model curriculum and guidelines for certifying driver-training schools.

Drivers' attitudes toward driving, their rest and off-duty habits, and their life-styles also affect accident potential. Intuitively, drivers who feel a professional responsibility toward their jobs, their employers, and the public should be more likely than others to observe safety regulations, exhibit good driving practices, and avoid situations likely to cause accidents. This thesis has not been thoroughly researched, however, and the role of driver attitude in heavy-truck accidents cannot yet be quantified.

Economic pressures also affect some drivers and may influence their driving practices. Those who are paid by the mile may resist taking adequate time off for meals and rest, and the fatigue that results may increase the likelihood of their being in an accident. Some owner-operators, pressed by inflation in operating costs and high interest rates on their truck loans, also may drive too long without sufficient rest. Information directly relating driver economics to accident experience is needed to help develop solutions to these problems.

Driver use of alcohol does not appear to be a major factor in truck accidents. In fact, existing data indicate that in car-truck accidents it is more often the car driver than the truck driver who is "under the influence" (L.S.S. Lohman and P. Waller, Trucks: An Analysis of Accident Characteristics by Vehicle Weight, Highway Safety Research Center, University of North Carolina, Chapel Hill, September 1975). A NHTSA contractor is currently studying this issue (Identification and Testing of Countermeasures for Specific Alcohol Accident Types and Problems, NHTSA Contract No. DOT-HS-9-02085, Calspan Field Services, Inc., Buffalo, NY). The influence that driver medical conditions have on accident probability is also an unknown. BMCS requires interstate drivers to have periodic medical checkups, but whether this has helped to prevent accidents has not been determined empirically.

Data Sources and Limitations

Some data exist on drivers who are involved in accidents, but few could be used to establish causation.

BMCS. The BMCS files contain some information about drivers of trucks involved in accidents. The information is limited, of course, to drivers operating in interstate commerce. Further, because it relies on self reporting, the information on safety belt use, hours of driving, physical condition, and other potential lapses could be inaccurate. Information or analysis is needed to determine whether inaccurate reporting is sufficiently frequent to cause any appreciable skewing of the aggregate data.

FARS. The state reports which the FARS files are based vary in their inclusion of questions about drivers involved in fatal accidents. Therefore, although the FARS data might offer some information on causality, they would not necessarily be nationally representative.

NASS. As the NASS program expands, it could provide very detailed information on the drivers of heavy trucks that are in accidents, if appropriate data elements were added to the report forms.

State Files. Although data on regulated, interstate drivers are available through the BMCS records on drivers, state files are the only source of records on intrastate drivers and these files vary considerably in quality. They rely on police reports of accidents, which generally do not include detailed information on the drivers. A driver's history within a particular state may be available, but usually it would not be in the same file as information on the accident in which the driver is involved. The two data sets would have to be matched in order to relate driving history to a particular accident.

Exposure Data. Researchers have attempted to conduct driver surveys at roadsides and truck stops (For example, see D.D. Wyckoff, Truck Drivers in America, Lexington Books, Lexington, MA: D.C. Heath and Co., 1979). It is suspected that drivers avoid such surveys, however. Further, there is no guarantee that the surveys will produce representative samples of all types of heavy-truck drivers. Driver exposure data are necessary, however, in order to study accident-involvement rates by driver characteristic. New methods are needed to gain this information.

None of the existing data files provides all the information needed for all types of heavy-truck drivers. It is important for purposes of causal analysis of driver-related factors in truck accidents that drivers be identified by type--regulated or unregulated, interstate or intrastate, company driver or owner-operator. Beyond this breakdown, a distinction should be made among owner-operators. Some operate under permanent leases to larger carriers and must abide by the same rules and regulations as drivers for those companies; some trip-lease to regular carriers; some obtain their loads through brokers; and some obtain their own loads. Both accident and exposure data by types of drivers are needed to compare accident rates for each group.

Potential Sources of Data

It is possible that some other data sources might supplement present ones to produce additional information on the role of drivers in heavy-truck accidents. Some likely sources are noted below.

Trucking Companies. Many carriers keep very detailed records on their drivers, and these records may permit identification of some driver characteristics that affect truck safety. For example, Yellow Freight System, Inc., conducts ongoing studies of vehicular accidents on a monthly and yearly basis. One study completed at the conclusion of 1980 indicated that because of economic conditions (lay-off of many drivers with seven years or less seniority) and less highway exposure, Yellow Freight System experienced a 47 percent reduction in road accidents for 1980 compared with 1979.

By identifying companies that have good driver record systems and obtaining permission to use their records (assuring them of individual confidentiality), it may be possible to learn more about the relative importance of various driver characteristics in safe driving.

Insurance Companies. Companies that insure heavy-truck drivers must have some basis for setting insurance rates. These companies could be contacted for permission to examine the records they use for rate setting.

Special Data Bases. Private researchers have conducted heavy-truck studies that may include information on drivers (For example, see Vallette et al., op cit.; K. Perchonok and T.A. Ranney, Analysis of Truck, Tractor/Trailer Accident Data, Final Report ZN-5926-V-1, Calspan Corporation, Buffalo, NY, June 1976; and T.A. Ranney, Analysis of Heavy Truck Accident Data, Calspan Field Services, Inc., Buffalo, NY, September 1978). These special studies may suggest hypotheses to investigate in future special studies or when additional data become available. A literature search could unearth these sources.

MDAI Approaches. In-depth investigations of heavy-truck accidents could help identify driver factors involved in those accidents. The University of Indiana has used this approach to study causes of passenger-car accidents (J.R. Treat, N.S. Tumbas, S.T. McDonald, D. Shinar, R.D. Hume, R.E. Mayer, R.L. Stanisfer, and N.J. Castellan, Trilevel Study of the Causes of Traffic Accidents, Final Report, Vols. 1 and 2, Institute for Research in Public Safety, Bloomington, IN, March 1977), and that model might be used for heavy trucks, as well.

VI. SUMMARY

Workshop participants generally agreed that data that could be valuable in helping to examine heavy-truck accident causation do exist in a variety of sources. The task ahead is to locate, examine, and--where possible--collate such data.

Major Data Issues

Two important areas of data deficiency surfaced in most of the workshop group discussions and in the colloquy that followed delivery of the group reports.

The first general issue was the role of economic factors in truck operations and driving practices. Little is known about how general economic conditions, such as inflation, and special ones, such as strikes, affect trucking operations. Data that might indicate whether present economic incentives encourage dangerous practices in trucking and how deregulation might change these incentives are generally lacking.

The second way in which most truck accident data are deficient is that they are categorized too coarsely for meaningful causal analysis. Finer breakdowns are needed of exposure and accident experience of vehicles, drivers, and carriers, by type. "Heavy trucks", for instance, include a multiplicity of sizes, weights, and configurations, and these differences are relevant to safety performance. The owner-operator category also conceals significant variations. Some operate as individuals; others are under contract to major carriers. Although both must meet federal equipment and driving standards, assuring compliance is much more difficult in the case of individual operators.

Each of the workshop groups also noted major issues within its area of concentration. The overview group stressed the importance of careful analysis and interpretation of the data that are available and of open publication for peer review of research results. The highway environment group's main concern was that, although highway conditions undoubtedly pose potential safety problems, these problems cannot be isolated by using present statistical data and methodologies. The vehicle factors group noted the same data difficulty as the highway group. It suggested that it may be necessary to combine the results of accident data analysis, engineering tests, and field evaluations in order to make sound decisions concerning vehicle-related countermeasures. The driver factor group observed that, although drivers and driving practices are responsible for a large proportion of the safety problem, these are the factors that are least amenable to change. If driver problems could be identified more precisely, however, it might be possible to ameliorate some of them directly through careful driver selection or indirectly through changes in vehicles and/or highways that would minimize driver limitations.

Potential Data Sources

The workshop generated suggestions for several sources of data on heavy-truck accidents that NHTSA might examine. These sources are generally varied in scope, in emphasis, in definitions, and in form, and data from them could probably not be aggregated. Nevertheless, they should be useful in helping to identify major safety problems in heavy trucking. These sources include:

1. Insurance company data. Insurance companies that insure carriers must have records that help them determine which companies to insure and at what rates. The insurance companies' criteria for granting insurance and the data on which those criteria are developed could help guide further investigation of specific problems.

2. In-depth investigations of specific accidents. State MDAI reports, such as those South Carolina has produced, also could provide important insights to heavy-truck accident causality, particularly if those reports included questions related to suspected problem areas that broader data sources do not address.

3. Other state data. Many states have made special studies and reports on types of accidents that are particular problems in those states but might not reach national accident data systems. Mountainous states' studies of truck runaways would be examples of such reports.

4. Federal agencies concerned with transportation--FHWA, NHTSA, BMCS, the Interstate Commerce Commission, and perhaps others--have carried out or contracted for projects that could be sources of information on truck accidents. Other such projects may be in progress or have been completed by universities, associations, or safety organizations. Even though some of these projects may not be confined to heavy-truck accidents, they may contain information on them.

5. It is in the carriers' interest to understand why their trucks have accidents, and they undoubtedly investigate the accidents that do happen. In addition, many keep consistent records over time, like those of the Yellow Freight System, that might help in problem identification. These could prove to be a valuable resource, particularly of information on driver factors--an area in which few data are currently available.

Though no one of these data resources could be considered complete or definitive, they do offer a potential for patching together a much wider and deeper picture of heavy truck accidents than we now have.

VII. OTHER PARTICIPANTS

Amoni, Marilena, U.S. Senate Commerce Committee, Subcommittee on Surface Transportation

Bailey, Tom, Maryland State Police
Barton, W.K., Transport Insurance Company
Bowie, Noble, Bureau of Motor Carrier Safety, Federal Highway Administration
Brady, Charles N., Highway Department, American Automobile Association
Brooks, Theodore E., Truckers Action Conference

Campbell, Carmen, U.S. Census Bureau
Chisholm, Jr., B.E., Virginia Department of State Police
Clarke, Robert, National Highway Transportation Safety Administration
Conda, Doug, Heavy Duty Truck Manufacturers Association
Crowe, Raymond R., American Road and Transportation Builders Association

Davis, Gerry, Bureau of Motor Carrier Safety, Federal Highway Administration
Deen, Thomas B., Transportation Research Board

Eicher, John F., Accident Investigation Division, National Highway Traffic Safety Administration

Fiste, Russ, Bureau of Motor Carrier Safety, Federal Highway Administration

Green, George D., Breeze Corporation

Harris, Claude, National Transportation Safety Board
Harrison, John F., American Association of Motor Vehicle Administrators
Hayden, Carl, Federal Highway Administration
Hedlund, James H., National Highway Transportation Safety Administration
Hensing, David J., American Association of State Highway and Transportation Officials
Hindle, Robert T., Matlack, Inc.
Hoskin, Alan F., National Safety Council

Krall, Farrel L., International Harvester Company
Kynaston, Edward E., Enforcement Services Division, California Highway Patrol

Lipps, Ronald D., Transportation Safety Division, Maryland Department of Transportation

McGee, Hugh, Wagner-McGee Associates
McKnight, A. James, National Public Services Research Institute

Najjar, Dan, National Highway Traffic Safety Administration
Neuman, William W., The Bevard Companies

O'Steen, Jim, Bureau of Motor Carrier Safety, Federal Highway Administration
Overbey, Charles, National Highway Traffic Safety Administration

Pachuta, John A., Pennsylvania Department of Transportation
Partyka, Sue, National Highway Traffic Safety Administration
Peck, Raymond A., National Highway Traffic Safety Administration
Pilkington, George, Federal Highway Administration

Ranney, Thomas A., Calspan Field Services Inc.
Reiss, Martin L., National Institute for Safety Research
Rheaume, Warren J., International Brotherhood of Teamsters

Scott, William, National Highway Traffic Safety Administration
Smith, R.P., Highway Safety Division, South Carolina Department of Highways
Stalknecht, Paul, New Jersey Motor Truck Association

Vierimaa, Donald W., Truck Trailer Manufacturers Association

Whitmer, Wallace E., Safety Legislation and Technical Coordination, GMC Truck & Coach Division

Zenker, Linda D., American Trucking Associations

OTHER INVITED ORGANIZATIONS

California Department of Motor Vehicles
Canyon Research Group, Inc.

Department of Transportation - Office of the Secretary

Fraternal Association of Steel Haulers

House Appropriations Committee
House Public Works and Transportation Committee

Institute of Transportation Engineers
International Association of Chiefs of Police

Liberty Mutual Insurance Company

Maine Department of Transportation

New York Motor Truck Association
New York State Department of Motor Vehicles

Office of Management and Budget

Private Truck Council of America

Senate Appropriations Committee

Western Highway Institute

APPENDIX C

DATA SOURCES

INTRODUCTION

This report made use of original data analysis as well as the results of studies in the published literature. This appendix is intended to focus primarily on what data files are available and pertinent to the accident experience of large trucks. It contains a description of the data files used in the analysis and of their limitations so that results can be properly evaluated. The appendix also includes a discussion of data system limitations, supplemental safety research to accident data systems, and recommendations for improved accident-data usefulness.

Throughout this report statistical results from previous research have been appropriately referenced. This section does not discuss the data sources used for those studies. It is assumed that the previous studies themselves contain the background necessary for evaluation of their conclusions. Where this is not the case, the authors of these studies are the best sources of further information on how their data were obtained. Similarly, numerous data collection efforts are not included in this section because they were discussed in their respective final reports or did not offer unique data for this report. This is not meant to imply disparagement either of the methods of obtaining the data or of the validity of the resulting estimates.

Several unpublished papers based on the data sources to be discussed have been prepared to support this report. A list of these papers is provided at the end of this Appendix. They are available from NHTSA's National Center for Statistics and Analysis (NCSA).

Further information on the original data sources used for this report is in the referenced coding manuals and analysis documentation as listed in the References.

ACCIDENT DATA FILES

Bureau of Motor Carrier Safety 50-T (MCS 50-T)

The Bureau of Motor Carrier Safety (BMCS) is an office within the Federal Highway Administration (FHWA). The main mission of the BMCS is to reduce the risk of commercial vehicle accidents and to decrease the resultant fatalities, injuries, and property losses. One of the means to accomplish this mission is a Federal accident reporting requirement as set forth in the Federal Motor Carrier Safety Regulations (FMCSR). BMCS collects and automates truck accident data submitted by motor carriers subjected to the Department of Transportation (DOT) Act on a form called MCS 50-T. Requirements for filing the 50-T accident form are described in Section 394 of the "Federal Motor Carrier Safety Regulations and Noise Emission Requirements" (BMCS, 1979). This form is required when an accident involves a motor vehicle engaged in the interstate, foreign, or intrastate operations of a motor carrier who is subject to the DOT Act. The accident must be reported if it results in the death of a human being, or total property damage exceeds $2,000, or bodily injury to a person who, as a result, receives medical treatment away from the scene of the accident. Motor carriers must report fatal accidents immediately and submit information on nonfatal accidents within 30 days. Approximately 30,000 accidents are reported annually. Data from 1973 through 1979 have been automated.

A limitation of the BMCS accident data base is that it includes data only for interstate carriers. Intrastate carriers are not subject to the FMCSR and therefore, are not required to submit accident reports. Also, some accidents for which reports are required may go unreported.

The information provided by the motor carrier is not verified from independent sources. Thus, care must be used in interpreting answers to questions which might imply fault or non-compliance with laws and regulations. Nevertheless, the self-reporting system is valuable in that it can collect data that is more difficult to obtain through other means, such as vehicle and cargo weights.

The BMCS 50-T data are a good source of data on accidents, injuries, and fatalities for different groups of drivers, vehicles, and highway environments.

Fatal Accident Reporting System (FARS)

FARS is a computerized data base containing information on all police-reported fatal motor vehicle accidents in the United States. It is an ongoing data collection program of NCSA. The data are drawn from various sources, which generally include police accident reports, driver license files, motor vehicle registration files, records from bureaus of vital statistics, and state highway department records. These are occasionally supplemented by emergency medical service reports and hospital records. Data for the FARS file are supplied by the States on standard forms. Each accident in the data base involves at least one fatality which has occurred on a highway. The FARS definition of a fatality is a death which occurs within 30 days of a motor vehicle accident and is the result of the accident. Data on approximately 300,000 fatal accidents from 1975 through 1981 have been automated. About 34,000 involved a large truck.

FARS is a national census of the most serious part of the safety problem--the loss of human lives--but it has significant limitations. Though it provides some information on fatal accidents as reported by each State, it cannot supply the national distribution for all accident severities. It lacks information on nonfatal injury and property-damage-only accidents for purposes of comparison. However, this problem can be overcome by intelligent use of broader-based accident files. Another problem is lack of information about the type of truck involved in the fatal accidents reported. This is largely the result of variance in the methods of classifying vehicle types in the record-keeping systems used by the 50 States and the District of Columbia.

Increasing the detail required in the forms could have the unfortunate result of less data or a reduction in the quality of data because many States might not be able to provide the information in the specified categories.

FARS data are a good source of total fatality counts by gross truck type and by the types of other involved vehicles and can be supplemented by nonfatal accident files for greater utility in analysis.

National Accident Sampling System (NASS)

NASS is another data collection effort of NCSA. The program is sponsored by NHTSA and supported by FHWA. Its objective is to provide nationally representative estimates for all police-reported accidents. Accident investigation teams under NHTSA contract are trained in the use of a standard set of data collection forms, and quality control contractors are employed to review the accuracy of the data submitted by the accident investigators to ensure uniformity in the data. Ten teams began operation in 1979 and have collected information on more than 3,000 accidents, of which over 300 involved a large truck. The NASS program calls for establishment of 75 teams. This expansion will greatly improve the precision of national estimates.

The major limitation of NASS is the small number of teams investigating accidents. Until more teams are operating, the national estimates of truck accidents produced from NASS will be crude. However, even with full implementation of NASS, no one data collection effort can provide all the necessary information. To answer specific questions, special studies can be designed within the NASS framework and particular situations can be over-sampled for increased precision.

The NASS data are a good source of detail on accident sequence and resultant injuries. When complemented by FARS, they are useful in describing the scope of large-truck accidents and their consequences.

The National Crash Severity Study (NCSS)

NCSS was an accident data collection program of NCSA that involved a random sample of accidents that resulted in car tow-aways. It was conducted by seven investigation teams under contract to NHTSA. Data on more than 12,000 accidents were collected from January 1977 through March 1979. More than 400 of these were two-vehicle accidents involving a car and a large truck. As with NASS, the resultant data can be used to produce estimates of relative frequencies of events. However, in the case of NCSS, the sample frame was the seven geographical areas where the teams were located rather than the entire country.

The NCSS data are limited in that they only contain those large trucks which were involved with a passenger car that was towed from the scene of the accident. However, the data that were collected included detail on crash configuration and injuries received. Because of the tow-away criterion, these were on average more serious accidents than those investigated by NASS. Because the individual NCSS team areas were not selected randomly, the cases represent only the experiences in the NCSS areas. However, these areas were a judgment sample that included both rural and urban environments and a scattering of geographical locations. Thus, the results from this data were indicative of the national experience and, given certain assumptions, can be used to estimate national totals.

The NCSS data are a good source of injury consequences in serious car-truck accidents, and provide details on types of collision.

Collision Performance and Injury Report (CPIR)

The CPIR file is a compilation of multi-disciplinary accident investigations (MDAIs) sponsored by NHTSA, the Motor Vehicle Manufacturers Association (MVMA), and the Canadian government. From 1967 to 1980, 470 accidents involving large trucks were investigated.

The major limitation of the data is that cases were selected by approximately 40 different teams over many years and under no single sampling plan. Thus, the data are not representative of any known population of accidents. As a result, questions about the frequency of accident characteristics are not answerable using CPIR data.

However, the data can provide insight into the characteristics of large-truck accidents, the sequence of events in accidents, the performance of vehicles, and injuries sustained by occupants of the large trucks and of the other vehicles that collide with them. This insight can be used to form hypotheses testable by more representative data.

State Accident Files

The data files of seven States--North Carolina, New York, Colorado, Maryland, Michigan, Washington, and California--were available to NCSA within the time limits of this project. The accident data files for the first six States were available through contracts with NHTSA. The California accident data were acquired by direct request to the State.

The difficulties of combining State files arise from their varied record-keeping systems and are similar to those described for FARS. However, FARS analysts review the individual accident diagrams and narratives and attempt to complete a standard form; such a method is not possible using State automated files alone. The possibilities of using combinations of States to form a data base are therefore severely limited.

The advantages of the State files are the large volume of accidents (almost three million traffic accidents occurred in these seven States in 1978) and the longer periods of time that they have been in operation (pre-dating most Federal data collections).

South Carolina's Specialized Accident Investigation and Surveillance Program (SIT)

South Carolina conducted in-depth investigations of fatal traffic accidents, most actively from 1970 through 1974, and collected data on 4,194 accidents. Of these, 273 involved a tractor-trailer. Although not automated, these cases were useful for the detailed questions and answers they included. Among these were conclusions by the team on the causes of the fatal accidents.

EXPOSURE DATA FILE

Truck Inventory and Use Survey (TIU)

TIU is an exposure data base collected every quinquennium by the Bureau of the Census as part of the Census of Transportation. Trucks were randomly selected for the survey from each State's motor vehicle registration files. (Vehicles owned by Federal, State and local governments were excluded from the 1977 survey.) Data were solicited by questionnaires mailed in 1963, 1967, 1972, and 1977 to the more than 100,000 individuals and companies in whose names the selected trucks were registered. More than 90 percent responded, probably because of the legal requirement to do so. The data can be used to produce national estimates which are as complete as the sample frame. The method employed has varied as the Bureau of the Census has attempted to improve its procedures, however, and as a result cross-year comparisons require familiarity with the development of the sampling methodology.

The most important limitation of the TIU is that it is truck-based for typical usage during the entire year. Questions about the driver cannot be answered meaningfully by this method. Also, the cargo weight, number of trailers, and other variable features are reported as a "best" answer or the "most frequently used." For example, many truck tractors may pull single trailers most of the time but pull double or triple trailers at other times. Because the information is obtained only for the "most frequently used" trailer unit, the less frequently used configurations may be underestimated. Consequently accident rates cannot be calculated in relation to exposure by cargo weight or trailers pulled.

For non-variable factors such as model year and size of carrier operation, TIU is a good source of national estimates of exposure. However, the accuracy of the resulting estimates is affected by the difficulty of obtaining complete truck-type profiles. This limits the usefulness of estimates which combine TIU with accident data.

The 1977 TIU sampling frame was based upon a census of State registrations, as compiled by the R. L. Polk Company. To meet its deadline, the Polk Company was forced to use incomplete data files. The FHWA Cost Allocation Study has devised its recommended method for adjusting the file to account for the undercount. It is recognized as being susceptible to possible future revision. It is this procedure which was used to produce the TIU estimates which are contained in this report.

Another difference between FHWA and NHTSA figures is the inclusion of Government vehicle estimates in the Cost Allocation Study. These estimates were not derived directly from TIU and therefore are not included in this report.

Also, the Cost Allocation Study included pickup trucks with registered weight over 10,000 pounds. This has not been done in this report in order to increase compatibility with FARS.

Finally, single-unit trucks pulling trailers have been classified as single-unit trucks for this report so that the estimates can be used with FARS. However, the Cost Allocation Study classified this configuration as an articulated vehicle.

DATA SYSTEM LIMITATIONS

The Limitations of Accident Data Files

An accident data file is a listing of items of information about a number of accidents. The collection of each item of information requires the expenditure of a certain amount of manpower and time. The level of effort needed to collect 100 data items for each of ten accidents is roughly comparable to that needed to collect 25 data items for each of 40 accidents, as long as the same general areas of interest are covered by the data items chosen. This means that for a given level of resources any data collection system will always present a compromise between volume and detail. This is reflected in the three most prominent types of accident data files: police accident reports, compiled at the State level; NASS accident reports, annually compiled at the Federal level; and multi-disciplinary accident investigation files, an open-ended, relatively small collection of in-depth reports on accidents of special interest.

To determine the cause of a particular accident, the multi-disciplinary accident investigation is customarily chosen to provide a plausible, but subjective, explanation. However, the very process of eliminating non-pertinent factors in specific accidents on the basis of expert judgment renders it practically impossible to aggregate such individual cases for statistical inference. Moreover, the file of in-depth reports cannot constitute a representative sample of the universe of similar accidents. It is therefore not even possible on the basis of such investigations to make a meaningful statement with regard to the relative distribution of causal factors.

The accident data files generated by compilations of police reports present different obstacles to effective analysis. Although well suited to the purpose for which they are designed, their information content is usually too sparse for analytic inference. Only in rare instances is it possible to undertake analysis of one of the potential causal factors identified in police accident reports, and then usually only with a number of plausible but unproven assumptions.

The NASS data collection system offers an accident file which, upon full implementation, is capable of providing information in sufficient detail and adequate volume to permit a variety of investigations into the causes of accidents. However, it should be recognized that for NASS, as for any other suitably designed accident data file, this capability is limited. It should also be kept in mind that all accident files based on police reports of accidents are necessarily incomplete and biased because many accidents are never reported. While it is recognized that the incidence of reporting is good for accidents resulting in fatalities and injuries, little information is available on the number of unreported, less severe accidents. A current NCSA study seeks to provide needed data on both the magnitude and characteristics of unreported accidents.

<u>The Limitations of Exposure Data Files</u>

Existing files of exposure data consist of a set of listings, such as of registered vehicles, vehicle miles of travel, and licensed drivers. The reliability and accuracy of such listings is unknown. It is conceivable that the results of such enumerative surveys as FHWA's Highway Performance Monitoring System (HPMS) and the National Personal Transportation Survey (NPTS) eventually can be converted into exposure data inasmuch as the two surveys are capable of correlating vehicle type, speed, volume, and road type, as well as of establishing other groupings.

A file of exposure data should meet two requirements:

- The data should be in definitional agreement with the corresponding accident data; and

- The information to be collected should meet the needs of the analysis plan it is to serve.

Constraints imposed by the second requirement make it impossible to design an "all-purpose" system to collect exposure data. The analysis plan determines the combination of factors in accidents that is to be scrutinized, and the exposure data file must match these factor combinations. This means that the data on all factors being studied must be collected simultaneously for each unit of observation (e.g., each vehicle). As a result, any one study can cover only a limited number of factors, and the effective compilation of exposure data crucially depends on the quality of long-range planning for accident research. The inadequacy of existing exposure data is demonstrated throughout this report. Without exposure data it is not possible to calculate accident or injury rates, or to arrive at conclusions about the relative risk associated with specific driver, vehicle, and highway/environment conditions. For example, it is possible to examine the distribution of large-truck accidents by time-of-day, or by weather and pavement conditions, but, without exposure data the analyst cannot determine whether these factors are linked to accident causation or whether they only reflect travel patterns.

SUPPLEMENTAL SAFETY RESEARCH TO ACCIDENT DATA SYSTEMS

Because accidents are rare events, it is never possible to obtain a complete roster of accident-factor combinations adequate for inferential analysis. Accident data can only provide a certain level of detail because of sample size limitations. Accordingly, causation research cannot rely exclusively on accident data. If certain types of detailed questions are to be answered, real-world and laboratory experiments, and computer models must be used to fill the information voids. In this case, however, accident data can be used to guide the researcher in devising effective study designs.

To supplement analysis of accident-data files, a number of methods are available to researchers, including: (1) controlled field studies using actual accident involvement; (2) driving simulators with which conflict situations can be simulated and responses can be measured in a controlled and repeatable manner; and (3) controlled experiments either in the laboratory or in actual traffic. Each of these methods has advantages and disadvantages.

Controlled field experiments have the marked advantage of using real-world accident involvement of comparison groups. If the reason for utilizing a controlled field experiment is to evaluate the benefit of a countermeasure for a vehicle fleet, and if one fleet of vehicles equipped with that countermeasure has significantly fewer accidents, deaths, or other injuries than an equivalent fleet without the countermeasure, then the effectiveness of that countermeasure has been defined at least for the same particular set of operating conditions and practices. The major problems in using of this method are cost, time, and extrapolation of results to the larger population. Adapting a countermeasure to a controlled group can be costly to implement. Moreover, there are costs associated with the collection and analysis of the accident data from the controlled group and with monitoring the group throughout the study to ensure that conditions do not change. Finally, such studies require extensive time to collect data on a significant number of accidents for statistical analysis. Notwithstanding these problems, the controlled field study could be a preferred method for problem identification and evaluation of specific countermeasures because it uses actual accident data as the measure, and hence does not require additional efforts to support or interpret the results.

The major advantage of driving simulators as a research tool is that they permit careful control of many variables that cannot be controlled in the real world. It is possible to simulate hazardous situations, often with considerable realism, that cannot be duplicated in the real world for humanitarian reasons, and although simulators are costly to develop, they may be reasonably economical to operate. Yet, no matter how realistic simulators may be, test subjects remain fully aware that even if they are involved in an "accident" they will not suffer harm. Also, it is often difficult to achieve a high degree of realism in simulation, making it yet more difficult for test subjects to become "involved" in the simulated driving. This casts some doubt on the validity of research results. At best, simulator studies must rely on criteria which fall short of the ultimate criterion--actual accident involvement. However, driving simulators can be a useful research tool for problem identification and initial countermeasure development.

The third research tool, controlled experiments conducted either in the laboratory or in actual traffic, also must rely on fictional accident involvement, but this method can often be used at relatively low cost, thereby permitting systematic examination of relevant variables as part of problem identification.

RECOMMENDATIONS FOR INCREASING THE UTILITY OF ACCIDENT DATA FOR THE STUDY OF LARGE-TRUCK SAFETY

The analysis done by the NCSA to support this report demonstrates that there is no single authoritative source of data on accidents involving large trucks which contains both the volume of cases necessary for accurate representation of the national truck population and the detail necessary for analysis. While analytical studies produce hypotheses about causative factors, enumerative studies put these results in the context of the entire safety problem and enable decision-makers to set priorities based upon estimates of the potential reduction in fatalities, injuries, property damage, and other measures of societal costs. The impracticality of creating a data file for both analysis and enumeration, combined with the need to both analyze and enumerate, implies that multiple data collection systems are necessary.

To improve the analyst's ability to synthesize the various sources of data, some modifications to the existing systems are needed. Three suggestions to improve data file compatibility follow.

1. The range of methods used in Federal data systems to classify truck types has been described by Partyka (1981). Inconsistencies among data files include the methods of coding body type, weight, use, and type of cargo.

Since classifications differ among these sources, they cannot be used in combination effectively. This results in an inefficient use of data that are expensive and time-consuming to collect. Therefore, data definitions should be standardized as much as possible without compromising the analytical needs of the various Federal agencies.

2. State-collected accident data are potentially useful for estimating national totals. Presently they are limited by the incompatibility of most data groups. This was documented by Najjar (1981) in an attempt to augment Federal data with those from seven States. A uniform set of coding rules could dramatically increase the usefulness of State data.

3. A major difficulty encountered in the analysis by Najjar was that TIU data were based upon an undefined subset of all large trucks. Similar problems are encountered when using BMCS 50-T data because little is included about motor carriers not regulated by the ICC. Thus, available data files overlap in ways that are not completely understood. A system of cross-file checks would reduce the effect of this overlapping. For example, any data source to be used with the data on predominately ICC-regulated trucks that are in the BMCS file should have an element that identifies the truck as ICC-regulated for comparison purposes. Similarly, to estimate the effect of the missing portion of the truck population on the computation of fatality rates, the TIU form should ask whether the truck was involved in a fatal accident in the year being studied. As a first step, an analysis of the current conditions of the files would help to define how the files overlap and which cross-file checks would be most useful.

Some modifications in individual data systems would increase the potential of each to identify problem areas of truck safety. Three suggestions for such improvements follow.

1. More emphasis should be placed on reducing the amount of missing data by investigator-initiated attempts or by analyst-supplied estimates of the unknown values, based upon known information. Missing data jeopardize the validity of the results of analyses of the available data because of the possibility of biases. It is important to know why data are missing and whether an assumption of randomness is justifiable despite that void.

2. Additional information on less severe accidents is needed as a control for more severe cases. An example of this need can be found in the unpublished paper on collisions with fixed objects by Partyka (1981). Collisions with roadside poles and guardrails that resulted in less severe results could not be identified because the struck object was not coded for non-tow-away, low-injury accidents. Selected items for less severe accidents should be available when they can be shown to be useful and collectible.

3. The 563 cases involving large trucks in the 1979-1980 NASS file are insufficient to answer the complicated questions of truck involvement. The completion of the full NASS system is needed for greater data volume, a wider variety of accident locations, and a consequent increase in the accuracy of national estimates.

Detailed exposure data based upon trip samples or day samples is also critically needed. The TIU method of summarizing a year's experience for a given truck with a single value cannot provide the information necessary to estimate accident involvement rates by subsets of such factors as driver characteristics, truck load weights, and types of cargo, all of which are believed to be associated with accident involvement. For this reason the "most frequent" value over the course of a year is inadequate for determining truck safety by subgroups.

Finally, it needs to be recognized formally that problem-solving is an iterative process and requires a long-term commitment by groups responsible for various aspects of safety research. To this end, flexible data collection systems like the NASS special study concept are useful tools. Most important, though, to the success of any such effort is the understanding that the most useful tool of any research is the well formulated question.

UNPUBLISHED SUPPORT PAPERS

- Heavy Truck Report to Congress Working Group Papers:
  Number 1: Car-to-Heavy Truck Crashes
  Number 2: Driver Factors Estimated from Accident Data
  Number 3: Environmental Factors
  Number 4: Single-Vehicle Accidents
  Number 5: Causes of Fatal Injuries
  Number 6: Fixed Object Collisions
  Number 7: Cross-Year Examination of Accidents
  Number 8: Accident Severity as a Function of Truck Size

- "A Comprehensive Approach to Truck Accident Data"

☆U.S. GOVERNMENT PRINTING OFFICE: 1982 381428 2392

25919

HE 5613.5 .L57 T52

DATE DUE

MTA LIBRARY
ONE GATEWAY PLAZA, 15th Floor
LOS ANGELES, CA 90012

DOT HS 806 300
September 1982

MTA DOROTHY GRAY LIBRARY & ARCHIVE
Large-truck accident causation.
HE5613.5 L37 T32
100000050953