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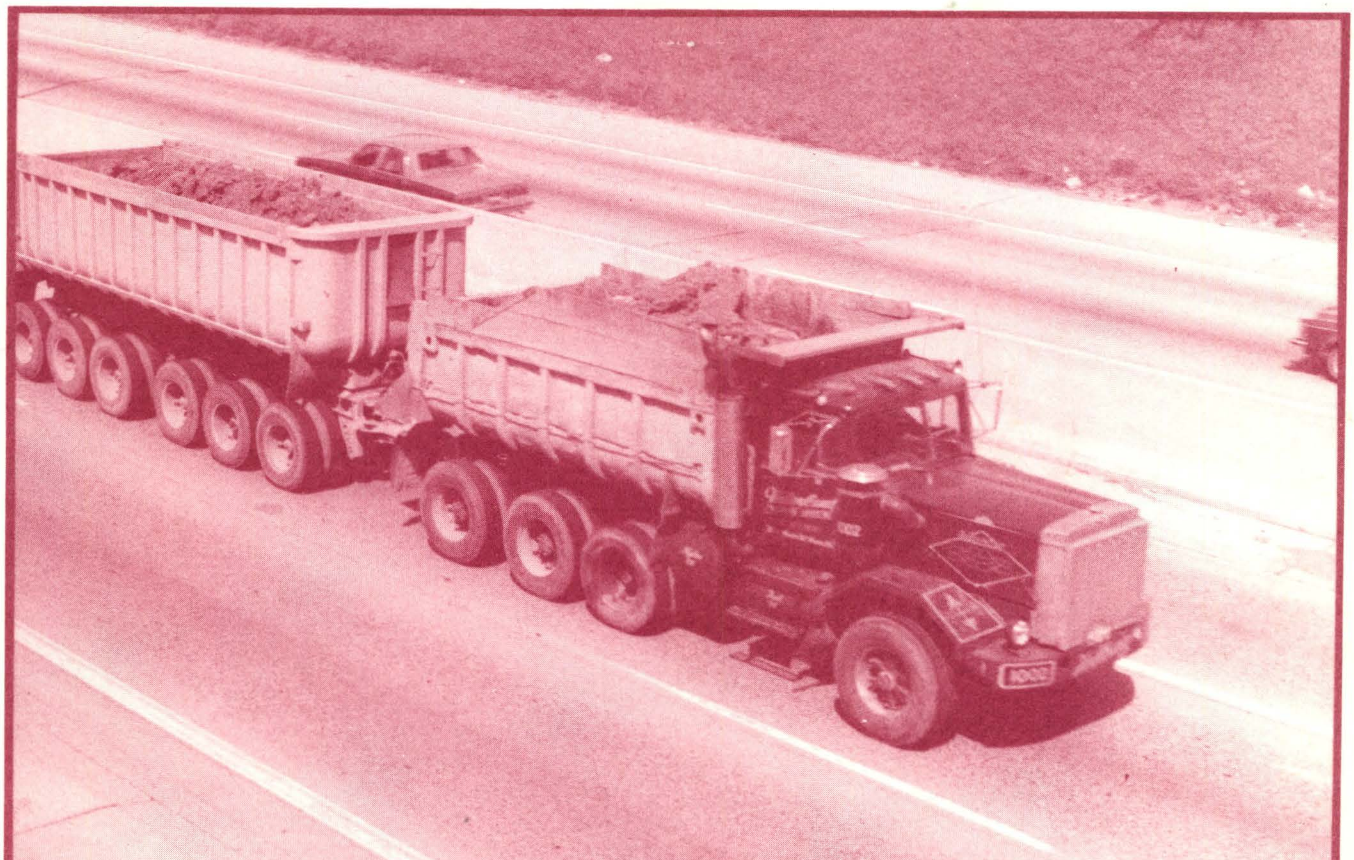
Examination of Truck Accidents on Urban Freeways

Publication No. FHWA-RD-89-201

December 1989



U.S. Department of Transportation

Federal Highway Administration

Research, Development and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101-2296

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FOREWORD

This report presents the results of a study to determine the nature and extent of truck accidents on urban freeways carrying a minimum of 100,000 vehicles per day with a minimum of 5 percent truck traffic. A truck is defined as a vehicle weighing at least 10,000 pounds. Traffic and geometric data were acquired for four segments of urban freeway in Detroit, Michigan, and one segment in Seattle, Washington, for a combined length of 46.5 miles. Accident data were retrieved from computer files beginning with January 1985 through September 1988. Hard copies of truck accidents were quality checked for accuracy by comparing the vehicle identification number (VIN) reported on the accident form against the manufacturer's code.

An estimate of the total annual cost of urban freeway truck accidents was determined to be $634,000 per freeway mile. This cost consisted of four components: (1) accident-related costs, (2) delay, (3) increased vehicle operational cost due to delay, and (4) clean-up cost. Expanding this estimate to the 1,937 Interstate and 560 urban freeway miles with average daily traffic volumes over 100,000 vehicles results in a nationwide cost of $1.6 billion.

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R. J. Betsold

R. J. Betsold, Director
Office of Safety and Traffic
Operations Research and Development

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Technical Report Documentation Page

1. Report No. FHWA-RD-89-201	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Examination of Truck Accidents on Urban Freeways		5. Report Date: December 1989
		6. Performing Organization Code
7. Author(s): Brian L. Bowman and Joseph E. Hummer		8. Performing Organization Report No.
9. Performing Organization Name and Address: Goodell-Grivas, Inc. 17320 W. Eight Mile Road Southfield, MI 48075		10. Work Unit No. (TRAIS): 3A4A1042
		11. Contract or Grant No.: DTFH61-87-C-00087
12. Sponsoring Agency Name and Address: Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296		13. Type of Report and Period Covered: Final Report July 1987 - July 1989
		14. Sponsoring Agency Code
15. Supplementary Notes: FHWA Contract Manager: Mr. Harry Lum (HSR-20)		

16. Abstract

The objective of this study was to determine the nature and extent of urban freeway accidents involving trucks, over 10,000 lb gross vehicle weight, and their consequences as a function of vehicle type and traffic and roadway characteristics. The study was limited to urban freeways and expressways with large total volumes (minimum 100,000 average daily traffic) and a significant percentage of large truck traffic (minimum 5 percent). The primary tasks involved a review of the literature, and the analysis of accident and operational data from selected urban freeway sites. A total of 2,221 verified truck accidents were included in the study occurring during 3.75 years on 46.5 miles of freeway. The study determined the characteristics of truck accidents, developed comparisons between truck and passenger vehicle accidents, and estimated the operational and economic consequences of truck accidents. An estimate of the total annual cost of urban freeway accidents was determined to be $634,000 per freeway mile. Applying this estimate to the total 2,497 Interstate and freeway miles, with volumes greater than 100,000 vehicles per day, that exist nationwide results in a nationwide annual cost of 1.6 billion dollars due to truck accidents on urban freeways. A Literature Review - Summary Examination of Truck Accidents on Urban Freeways (Report No. FHWA-RD-88-167), developed as part of this project, is available from NTIS.

17. Key Words: Heavy trucks, urban freeways, accidents, accident exposure	18. Distribution Statement: No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161		
19. Security Classif. (of this report): Unclassified	20. Security Classif. (of this page): Unclassified	21. No. of Pages: 101	22. Price

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

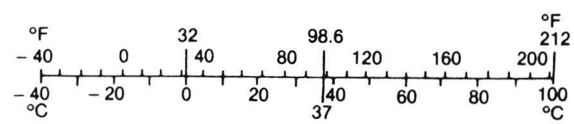
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

TABLE OF CONTENTS

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TABLE OF CONTENTS (CONTINUED)

Page

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

Figure | Page

LIST OF FIGURES (CONTINUED)

Figure | Page

LIST OF TABLES

CHAPTER 1 - INTRODUCTION

Trucks are an integral part of the United States' economy responsible for transporting the majority of the Nation's freight. The commodities transport needs require that heavy trucks have access to all retail, commercial and industrial sectors of society. This necessitates that trucks be able to use all, or at least the major portions of, urban freeways. The result is that urban freeways serve a diverse combination of high volume commuter traffic, local truck delivery traffic and long haul through truck traffic.

The demands placed on urban freeways are expected to increase. The increase in total vehicle registrations averages approximately 3 percent annually with approximately 4 million new trucks entering the fleet every year. The rate of growth not only results in increased urban freeway traffic demand, but the proportion of growth is also resulting in a greater percentage of larger combination vehicles. The ultimate results are an increase in congestion, traffic delays and accidents involving large trucks.

Much of the attention to traffic safety on urban freeways has concentrated on the issue of truck accident frequencies and rates. Often the results of studies of this issue are based on misleading or inappropriate analysis strategies. For example, accidents are categorized by the type of vehicle involved in the accident. If the accident involved a passenger car and a truck, it is categorized as a truck accident. Subsequent analysis of this accident will typically treat it as a truck accident using only truck exposure factors (such as truck million vehicle miles of travel) to normalize the data. This method accounts for the presence of the truck but it does not account for the presence of the passenger vehicle involved in the crash.

Implicit in the use of exposure factors in accident analysis is the premise that the greater the amount of travel on a given facility, the greater is the amount of risk or exposure to accidents to which vehicles on the facility are subjected. The proper use of rates must reflect the varying amounts of travel, or exposure to risk, of each element involved in the accident. Using the truck miles of travel is, therefore, valid only for analyses of truck-only accidents.

Another error propagated by the analysis of truck safety is the direct comparison of truck accident rates to their proportion of the traffic stream. This is an invalid comparison when multivehicle accidents are involved because it always overstates the accident rates of individual components of the traffic stream. This is especially true when these individual components constitute a small proportion of the traffic stream. For example, consider a situation where large truck traffic constitutes 5 percent of the vehicle miles traveled. Large trucks could, therefore, be expected to be involved in more than 5 percent of the two vehicle accidents since they can impact themselves as well as other vehicles on the roadway. Comparisons on the basis of vehicle miles traveled neglect this possibility and makes it appear that truck accidents are greater than what could be expected.

The objective of this study was to determine the nature and extent of urban truck freeway accidents and their consequences as a function of vehicle type and traffic and roadway characteristics. The study was limited to urban freeways and expressways with large total volumes (minimum 100,000 average daily traffic) and a significant percentage of large truck traffic (minimum 5 percent). The primary tasks involved a review of the literature, and the analysis of accident and operational data from selected urban freeway sites.

BACKGROUND

Much research has been performed on various facets of accidents involving large trucks in the United States. The results of this research were reviewed to determine if the magnitude of large truck accidents on urban freeways had previously been quantified and to identify problems, biases and validity threats encountered during previous large truck studies. Two major findings were apparent from the literature review. First, although many different researchers have looked at various facets of the problem, few research efforts were identified which concentrated on urban freeway truck accidents. Second, the review revealed that the conclusions of truck accident studies were often based on misleading or inappropriate analysis strategies.

In summary, none of the many data bases and methodologies used in prior studies were sufficiently comprehensive to yield the information required to assess the magnitude of large truck accidents on urban freeways.

MAGNITUDE OF LARGE TRUCK ACCIDENT EXPERIENCE

One of the few identified studies which examined accident rates (i.e, using vehicle miles traveled) in a manner which isolated urban freeways from other road types was performed in Texas.[1] The results from that study indicate that on 6 Houston freeways, trucks were involved in a higher percentage of accidents than their percentage of freeway volume. The study indicates that 18.5 percent of all accidents on the freeway segments involved trucks while trucks simultaneously accounted for 5.9 percent of total traffic volume. The Texas study also presented data on accident rates with Houston experiencing 0.7 accidents per million vehicle miles of travel (MVMT). The Texas truck accident rate (0.7 MVMT) is in agreement with other truck accident studies. The results of a study conducted in Los Angeles, Orange and Ventura Counties in California on 38 freeway segments disclosed a truck accident rate of 1.9 accidents per MVMT.[2]

Several studies have addressed truck accident involvements on rural and urban freeways without distinguishing between the two types of facilities. These studies, while not directly applicable to the current study, were investigated to determine if they could provide an indication to the extent of the urban freeway truck accident problem and possible analysis methods. Researchers predicted truck accident rates using regression equations based on 1970 and 1971 accident data from 55 freeway sites in Maryland.[3] Regression equations were developed for several accident types and the percent trucks and VMT proved to be significant independent variables. It was concluded from a study of State police accident reports and average daily traffic (ADT) estimates for a sample of Indiana roads that heavy trucks were much more involved per vehicle in accidents than passenger cars on rural Interstate highways.[4]

Meyers studied accidents from 1976 to 1978 on 34 limited access toll facilities, including 21 freeways and 13 bridges or tunnels across the United States, using detailed exposure data available from toll receipts.[5] The analysis of 73,500 accidents during almost 50 billion vehicle miles of travel led to the conclusion that light trucks (10,000 to 26,000 lb) were involved in 2.35 times more fatal accidents than passenger cars. It was also concluded that heavy trucks (over 26,000 lb) were involved in approximately 2.10 times more fatal accidents than passenger cars. Similar findings were claimed for injury and property damage only (PDO) accident rates. No breakdown between urban and rural toll facilities was provided. Jovanis and Delleur also examined accidents on a toll facility to take advantage of the exposure data available from receipts.[6] Their analysis of 1978 accidents on the Indiana Toll Road (a freeway with predominately rural characteristics) led them to conclude that the interactions between exposure, vehicle type, and accident rates are much more complex than previously imagined. For example, they found that high rates of involvement by autos in accidents were associated with high rates of truck exposure (i.e., high truck VMT). A recent look at truck accident rates on predominately rural freeways also used toll facilities to obtain the exposure data.[7] The analysis of 3 years (in most cases) of data from four facilities led to the conclusion that tractor-trailer trucks were over represented in multivehicle accidents, fatal accidents, and total accidents per mile of travel when compared with passenger vehicles.

Several researchers have used large national or statewide data bases to calculate truck accident rates without distinguishing road type. The general finding is that the number of truck-involved accidents is large and increasing with time. A noted study used the Fatal Accident Reporting System (FARS), the Bureau of Motor Carrier Safety (BMCS) accident data base, North Carolina accident data base, and other data from several years in the late 1970's.[8] The authors concluded that, in a truck-car collision, occupants of the car are more likely to be killed if the truck is heavy rather than light and that accidents involving heavy trucks are more likely to result in fatalities than other types of accidents.

A study of the FARS from 1975 through 1981 using FHWA exposure data indicated that combination trucks are over involved in fatal accidents in relation to the number of miles traveled.[9] In multivehicle fatal accidents between combination trucks and cars, the occupants of the car(s) were much more likely to be killed than the truck occupants. However, combination trucks were determined to be much less likely to be involved in fatal single-vehicle and pedestrian accidents. The FARS indicated that combination vehicle accidents and fatalities increased on all roads in the U.S. each year from 1975 to 1979, declined substantially in 1980, and increased again slightly in 1981. A rise in heavy truck-involved fatalities from 1975 to 1976 (from 2,858 to 3,338) using the FARS.[10] The author further broke down heavy-truck-involved accidents by road type, and determined that there were 127 fatal accidents involving heavy trucks on urban Interstates during 1975 and 183 during 1976. Other researchers, after examining several national accident data bases, concluded that injuries, fatalities, and numbers of accidents in which trucks were involved rose from 1974 through 1978.[11] A report based on NASS data determined that approximately 263,000 accidents, involving large trucks, occur annually in the U.S. and that about 13 percent of these occur on urban freeways.[12] By contrast, only about 5 percent of accidents not involving large trucks occur on urban freeways.

Researchers looking at State data have also provided useful numbers of truck involved accidents. A study of truck accident rates was conducted using several years of Michigan accident data and estimated VMT data from the Federal Highway Administration (FHWA).[13] The author concluded that tractor-trailers had a higher rate of fatal accidents than other vehicle types, but that pickup trucks, vans, and straight trucks had higher rates of PDO and total accidents. Data from Oregon indicate that there were 1,704 accidents involving trucks reported statewide in 1985 which resulted in 61 deaths, 951 injuries, and an estimated $20.6 million in property damage.[14] These totals represent 4.2 percent of all accidents reported, 11.1 percent of all fatalities, and 3.0 percent of all injuries reported, respectively, in Oregon. Several reports using statewide data from Michigan have concluded that accidents involving trucks are increasing annually after a low point was reached during 1982.[15,16] Further, the number of total accidents have increased at a much lower rate which means that relative truck involvement is increasing. Another report which examined BMCS accident data and the FARS data base as well as Michigan accident data from 1978 to 1984 found that Indiana, Michigan, and Ohio have all exhibited the same general trend of truck accident involvement; declining to 1982 or 1983 and then increasing afterwards.[17] A summary of the research on large truck accident experience is presented as table 1.

CHARACTERISTICS OF LARGE TRUCK ACCIDENTS

Two studies completed during the 1960's examined accident rates on different portions of freeway networks.[18,19] Although neither study examined rates for trucks separately from other vehicle classes, the findings help illustrate the accident problem. One examined data from a sample of 1,380 miles of urban freeway in 20 States.[18] The proximity to interchanges appeared to affect the accident experience of a given study section. The accident rate increased from an average of approximately 60 per 100 MVMT for freeway sections located 2 to 4 miles from an interchange; to over 120 accidents per 100 MVMT for sections within 0.4 miles of an interchange. Among interchange elements, the average accident rate was highest for the sample of entrance ramps (719 per 100 MVM), followed by exit ramps (370 per 100 MVM), deceleration lanes (186 per 100 MVM), and acceleration lanes (174 per 100 MVM). The other study examined a similar sized sample of California freeway ramps without separating urban and rural area types.[19] Off-ramps were determined to have higher accident rates than on-ramps. Left-hand ramps had the highest average accident rate of 10 ramp types with longer acceleration and deceleration lanes associated with lower rates.

Table 1. Summary of research results on large truck accident magnitude.

Reference Number and Year	Study Area	Facility Type	Summary of Findings
[1], 1984	Texas	urban freeways	Trucks comprised 5.9 percent of total volume and were involved in 18.5 percent of all accidents.
[2], 1985	California	urban freeways	Truck accident rate of 1.9 accidents per MVMT.
[3], 1974	Maryland	urban and rural freeways	Percent trucks and VMT were significant independent variables for several accident types.
[4], 1976	Indiana	rural interstate highways	Heavy trucks had a higher per vehicle accident involvement than passenger cars.
[5], 1978	Nationwide	limited access toll facilities	Heavy trucks were involved 2.1 times more fatal accidents than passenger cars.
[6], 1978	Indiana	toll roads	High rates of passenger car accident involvement were associated with high truck VMT.
[7], 1987	New York New Jersey Kansas Florida	toll roads	Tractor/trailer trucks were overrepresented in multivehicle fatal and total accidents when compared to passenger cars.
[8], 1981	Nationwide	not specified	Heavy trucks are overinvolved in fatal crashes for their VMT.
[9], 1983	Nationwide	not specified	Combination vehicle accidents and fatalities increased each year from 1975 to 1979 and in 1981.
[10], 1978	Nationwide	not specified	Heavy truck accidents on urban freeways resulted in 127 fatal accidents during 1975 and 183 during 1976.

Table 1. Summary of research results on large truck accident magnitude (continued).

Reference Number and Year	Study Area	Facility Type	Summary of Findings
[11], 1981	Nationwide	not specified	Large truck injury, fatal, and total accidents increased from 1974 through 1978.
[12], 1983	Nationwide	not specified	Approximately 263,000 accidents occur annually in the U.S. with 13 percent occurring on urban freeways.
[13], 1980	Michigan	all types	Combination vehicles have a higher fatal accident rate than other vehicle types.
[14], 1985	Oregon	all types	Statewide truck accidents resulted in approximately $20.6 million in property damage and represent 4.2 percent of all reported accidents.
[15], [16], 1986	Michigan	all types	Truck accidents are increasing annually after a low point during 1982.
[17]	Michigan	all types	Michigan, Indiana, and Ohio all exhibited the same trend in truck accident occurrence.

A comprehensive examination of truck-involved accidents on urban freeways was completed in 1984.[20] Detailed accident data were gathered from 78 sections of roadway in 6 States with exposure data by vehicle type obtained from State studies, films and special counts. Relative to truck accidents on urban freeways the authors concluded that:

- Most accidents occur on level or nearly level sections.
- Most accidents occur on tangent sections.
- Most accidents are not related to interchanges or ramps and, of those that do occur on ramps, more occur in the vicinity of off rather than on ramps.
- Some temporary condition on the roadway such as traffic congestion, construction, a previous accident, or a disabled vehicle was a factor in over 40 percent of accidents.

Researchers have examined truck type as a factor in accident rates. In recent years, the focus of many of these studies has been on the question of singles (tractors with one trailer) versus doubles (tractors with two trailers). An additional finding was that doubles experienced significantly more accidents than singles on urban freeways.[20] Subsequent analysis performed for the FHWA reinforced the initial conclusion that doubles were involved more often than singles. Data analyzed from Interstates indicated that doubles are involved over three times as often in single vehicle crashes and over twice as often in all crashes as single tractor/trailers.[21] Using data collected by the University of Michigan on a nationwide basis it was found that singles may have a somewhat lower involvement rate in fatal accidents than doubles, and that doubles are usually driven on higher quality roads by more experienced drivers.[22] The exposure data used were not very detailed, however, so factors which may have influenced these results (i.e., interactions) were not considered. A 1987 study used national accident data bases to demonstrate that singles and doubles have similar fatal and injury accident involvement rates but that doubles are underinvolved in collision accidents and overinvolved in every major noncollision accident type.[23]

Trucks involved in accidents on a sample of predominately rural Interstates in the State of Washington were compared to a control sample of trucks that passed the accident site 1 week after accident occurrence.[24] It was concluded that truck configuration was the predominant truck characteristic affecting accident rates with doubles 2 to 3 times more likely to be in crashes than singles.

A study of the BMCS accident data base determined that straight (i.e., single-unit) trucks and flatbed or tanker-type tractor/trailers also have high fatality and injury rates.[25] Additional analyses of the BMCS accident data file determined that most types of doubles and singles have higher accident involvement rates than straight trucks, although straight trucks were more involved when loaded than when empty.[26]

Time and environmental factors have been examined by many researchers in relation to truck-involved accidents. Specific to urban freeways, it was determined that:[20]

- There was an even distribution of accidents on weekdays (17 to 19 percent of the weekly total on each day) with 6 percent on Saturdays and 4 percent on Sundays.
- Only 14 percent of accidents occurred between 9 p.m. and 6 a.m.
- Seventy-two percent of accidents occurred during daylight hours and 15 percent occurred at night on freeways with street lights.

Time and environmental factors were identified for truck-involved accidents on a nationwide basis for all roads.[10] This investigation of 2 years of FARS data determined that:

- Truck-involved fatal accidents peak in July and are lowest in February.
- Friday is the peak day of the week for truck-involved fatal accidents, with a slow rise through the work week from about 15 percent of weekly fatals on Monday to over 18 percent on Friday, with Saturday and Sunday accounting for about 11 and 6 percent of weekly fatals.
- Heavy trucks are involved in 8 percent of all fatals rising to 10 percent of all fatals in rainy weather and 16 percent of all fatals in snowy or sleeting weather.

An analysis of the BMCS accident data base for all roads and all types of accidents resulted in different trends than those exhibited by FARS data.[27] For example, approximately 40 percent of truck-involved fatal accidents occurred during darkness on roads with no artificial lights. The trend for accidents occurring on different days of the week did not appreciably differ from the FARS results. Weather and light conditions were included as important variables in a study of accident rates by vehicle type on the Indiana Toll Road.[6] It was found that truck accident rates were similar for day and night conditions, that snow was a signficiant weather factor increasing accident rates for all vehicle types, and that large truck accident involvement rates were lower during rainy days. An analysis of the 1980 BMCS accident data base referred to earlier indicated that weather and light conditions have a small effect on fatality and injury accident rates for different truck types.[25] A summary of the research results on the characteristics of large truck accidents is presented as table 2.

CONSEQUENCES OF URBAN FREEWAY LARGE-TRUCK ACCIDENTS

Large-truck accidents on urban freeways can result in huge bottlenecks. It is not unusual for accidents involving trucks, due to their size and possible cargo spillage, to cause the closure of all freeway lanes. The result, combined with the large traffic volumes and limited access/egress characteristics of a freeway, can be enormous vehicle delays and associated costs. These costs are in addition to those customarily associated with traffic accidents. Those portions of the literature review pertaining to estimates of accident costs and methodologies for estimating delay costs due to a truck accidents are presented in this section of the report.

Estimates of national cost averages for various types of accidents are available from the National Highway Traffic Safety Administration (NHTSA), the National Safety Council (NSC) and others.[28,29,30] Use of the national accident cost averages for direct application to truck-accident consequences has several disadvantages. Most importantly, the estimates are national averages of all accident types and are not repre-

Table 2. Summary of research results on the characteristics of large truck accidents.

Reference Number and Year	Study Area	Facility Type	Summary of Findings
[18], 1968	20 States	urban freeways	The accident rate for trucks rises from 60 per 100 MVMT to over 120 per MVMT in the proximity of interchanges.
[19], 1981	California	urban freeways	Left-hand ramps had the highest average accident rate of 10 ramp types.
[20], 1981	6 States	urban freeways	Most truck accidents are not related to interchanges or ramps.
[21]	(summarized prior studies)	all types	Doubles are involved over three times as often in single-vehicle accidents and over twice as often in all accidents as singles.
[22], 1986	Nationwide	all types	Singles have a lower fatal accident rate than doubles.
[23]	Nationwide	all types	Doubles are overinvolved in every major noncollision accident.
[24], 1987	Washington	interstate	Truck configuration was the predominant truck characteristic affecting accident rates.
[25], [26], 1984, 1985	Nationwide	all types	Straight-trucks, flat beds and tanker type tractor-trailers have high fatality and injury rates.
[10], 1978	Nationwide	interstate	Truck involved fatal accidents are greatest in July and on Fridays.
[27], 1982	Nationwide	all types	Approximately 40 percent of truck involved fatal accidents occur during darkness on roads with no artificial lights.
[6], 1978	Indiana	toll roads	Truck accident rates are similar for day and night conditions and lower during rainy conditions.

sentative of the specific financial consequences of truck accidents. Urban freeway truck accidents are more costly than the national average accident due to the inherent potential for high vehicle and cargo costs in addition to the possibility of incurring clean-up costs for cargo spillage. The literature review did not identify any research that attempted to estimate costs for urban freeway truck-related accidents. In addition, the estimates from the various agencies differ drastically, with controversy existing over which set of estimates is most appropriate.

Typical estimates for accident costs do not include the costs associated with the delay of vehicles not involved in the accident. Such costs can be substantial for incidents on high-volume freeways and must be considered in determining the consequences of truck-involved accidents. Computerized traffic models of urban freeways are available to aid in determining the delay resulting from an accident. A computer model for estimating traffic congestion on urban freeways due to incidents was developed for the FHWA.[31] The model requires the user to input the capacity of the freeway under study for both free-flow and bottleneck conditions.

DATA ANALYSIS METHODS

The analysis of traffic safety issues is typically conducted by investigating accident frequencies or rates. Conclusions based on the analysis of accident frequency alone are sometimes prone to erroneous conclusions since this method does not take into consideration the likelihood of event occurrence. For example, an intersection that has twice the traffic volume can be expected to have more accidents than a lower volume intersection simply because there are more opportunities for accidents to occur. The consideration of accident frequency will, however, identify the high volume intersection as the most hazardous simply because it had a higher number of accidents. An accident rate on the otherhand is the result of dividing the accident frequency by a measure of traffic volume. In the previous example, the intersection with twice the volume requires twice as many accidents in order to equal the accident rate of the lower volume intersection. The use of accident rates, therefore, tends to provide a more accurate estimate of event occurrence since it normalizes the frequency by the number of opportunities.

The use of accident frequency is often used to obtain an insight into accident magnitude when accurate volume or exposure data is not available. The FARS, for example, provides information on the number of traffic fatalities classified by vehicle and accident characteristics. This information is useful in determining annual trends but without additional data or vehicle miles driven it does not permit the determination if a heavy truck is more likely to be involved in an accident than a passenger vehicle. Thus, an analysis of accident frequency on a nationwide basis or on a sample of all urban freeways would have limited advantages for the analysis of urban freeway truck accidents.

Accuracy of Exposure Measures

The greater the amount of travel on a given facility, the greater is the amount of risk or exposure to accidents to which vehicles on the facility are subjected. Accident data analyses are typically expressed as accidents per vehicle miles for roadway segments and accidents per number of vehicles for roadway spots. As expected, the accuracy of this method depends on the accuracy of the vehicle counts. Roadway agencies typically conduct a 24-hour vehicle count and use this count as the Average Daily Traffic (ADT). This method of conducting counts and using the results without adjustment is understandable in light of the large number of roadways under the jurisdiction of individual roadway agencies. The accuracy of these counts is usually sufficient for the needs of the highway agency performing the analysis. But more accuracy is needed for performing an analysis on the relative magnitude of the accident occurrence between different segments of the vehicle population.

Determining the accident experience of large trucks on urban freeways requires accurate estimates of total vehicle volume as well as the number of large trucks present in the traffic stream. The number of large trucks is typically estimated by performing short manual counts of the trucks passing a spot on the roadway. The truck count in conjunction with the total volume is used to obtain a percent-truck-mix figure. This measure is not only prone to error, due to the short sampling time, but is typically not conducted on a periodic basis due to manpower constraints. As the study area becomes larger, it becomes progressively more difficult to control the accuracy of the volume count and percent vehicle mix used to develop the accident rates. Conclusions based on large areawide studies are, therefore, prone to error.

Some prior studies conducted their analyses from toll roads and turnpikes that provided reasonably accurate counts of truck type, volume and passenger vehicle volumes.[5,6,7] The different accident reporting and toll booth data collection practices for even those relatively controlled data collection environments required manual accident record inspection to remove possible errors; such as pick-up trucks being coded as single-unit trucks.

Propriety of Accident Rate

The use of rates for traffic accident analysis provides a better measure of relative safety than the use of accident frequencies. Care must be exercised, however, when analyzing a segment of the total accident population to ensure that the accident rates and analysis methodology used provide an unbiased measure of what is actually occurring.

Traditional Method of Determining Exposure

The use of accident rates poses conceptual and procedural problems when analyses of specific accident or vehicle types are performed. The problems stem from determining an appropriate measure that properly reflects the propensity of accident occurrence. This problem has been recognized and addressed in different ways. The traditional approach is to categorize an accident by the type of vehicle involved. If one truck is involved in the accident then the incident is typically categorized as a truck accident, and the total vehicle miles traveled (VMT) for only trucks during the analysis period is divided into the number of accidents. This approach has the fault, therefore, of attributing accidents involving more than one vehicle type to only one type of vehicle. For example, Michigan recorded a total of 84,640 truck accidents during 1977; where a truck accident is defined as one that involves at least one truck. These truck accidents involved approximately 90,000 trucks and 63,000 nontrucks. The majority of truck accidents are, therefore, the result of conflicts between trucks and nontrucks. The traditional exposure measure, however, does not consider the exposure effect of the nontrucks. The results are truck accident rates that are of a larger magnitude than they would be if the nontruck exposure was also considered.

Induced Exposure Methods

The problems associated with obtaining accurate exposure data prompted Thorpe, in 1964, to propose a method for determining exposure by using information routinely available from most accident reporting systems. [32] The basic premise behind the idea, commonly referred to as method of induced exposure, is that the relative exposure for certain classes of drivers, vehicle types, driving environment, etc. is proportional to the number of times that the analysis category is an innocent victim in collision accidents. The advantages of such an induced measure of exposure is that the population at risk can be determined both quickly and economically. In addition, it would generally be based on large samples. In order to develop his model Thorpe introduced the following assumptions:

1. Single-vehicle accidents are caused entirely by the actions of the vehicles which are involved in the accident.
2. Multiple-vehicle accidents are caused by the first two vehicles to collide and in such a collision there will be a responsible and an innocent victim driver-vehicle combination.
3. The proportion of responsible involvements in multicar collisions pertaining to each group is equal to the proportion of single-car accidents pertaining to that same group.

4. The proportion of innocent victim involvements pertaining to each analysis group is equal to the proportion of total exposure pertaining to that group (i.e., will constitute the exposure distribution).

The potential advantages to Thorpe's method were recognized, but the assumptions related to single-vehicle accidents drew considerable criticism. Part of the criticism resulted from the fact that the assumptions did not allow for crashes resulting from vehicles being run off the road by an unidentified vehicle or other unforeseen circumstances which might result in a single-vehicle crash with an innocent driver. The induced exposure model actually permitted the determination of the exposure without obtaining vehicle counts or knowledge of the distribution of responsibility for each individual accident. According to the model, for example, exposure by driver age group was obtained solely from the number of single-car accidents experienced by each age group being analyzed. Several studies investigated induced exposure using models different from the original model but based on similar concepts. Haight used Thorpe's basic idea but changed the specific formulation so that greater demands were placed on accident information.[33] Koornstra introduced an induced exposure model which made more detailed use of the available accident data.[34] This model suggested that single-vehicle accidents be treated as two-vehicle accidents where the second vehicle belongs to a ficticious "dummy" category. Mengert assessed the validity of the Koornstra-type and Thorpe-type induced exposure models, by applying the exposure estimates to actual accident data, and determined that they did not provide credible estimates of exposure.[35]

Other studies considered induced exposure based on models that used the assigned responsiblity.[36,37,38] These models, often called quasi-induced exposure models, investigated the accident reports to find who the investigating officer determined was most at fault in initiating the accident. This method then, uses additional information from the accident reports not used by proponents of the strict induced exposure models. A study by Carr is of particular interest because he offered evidence contrary to Thorpe's hypothesis: that the proportion of each group in a single-vehicle accident equals the proportion of the group as a responsible party in two-car collisions.[36] He determined that assigning responsibility, and subsequently exposure, by using police citation information instead of single-vehicle accident occurrence gave dependable results.

Cerrelli used the quasi-induced exposure method (i.e., that method which assigns responsibility based on actual police reports or citations) to develop a liability index for different driver groups.[38] The liability index was found to agree well in a proportional sense to insurance rates. Subsequent analysis performed on Cerrelli's exposure estimates determined that they were comparable to other estimates that were obtained in a third independent study.[39] Recent work also obtained results which are considered as being reasonable.[40,41] Use of the quasi-induced exposure method, therefore, seems to provide an alternative method of analyzing truck accidents which will provide accurate estimates of actual truck exposure. Using the quasi-induced exposure method entails the use of two assumptions:[41]

1. The likelihood of a vehicle being an object (the second vehicle) of an accident is proportional to the exposure of that vehicle.

2. The likelihood of a vehicle being the object of an accident is equal to the likelihood of another vehicle being the object if the exposure of the two vehicles is the same.

What this is essentially saying is that the number of times that a vehicle-driver combination is involved in an accident; when the driver of that vehicle is an "innocent victim", is proportional to the exposure of that vehicle-driver combination on the roadway. It is entirely possible that the use of the quasi-induced exposure method can yield drastically different results than those which are customarily achieved through the use of vehicle miles traveled or number of entering vehicles. The reasons for this discrepency can be two-fold. The first reason can be that the quasi-induced exposure method does not provide a reliable method of estimating exposure. The second possibility is that the traditional methods of directly ascertaining exposure are biased due to systematic tendencies to over- or underestimate actual mileage.

With regard to the first concern, Maleck and Hummer performed a study that compared accident rates based on traditional methods of exposure estimation and the quasi-induced exposure method.[41] The analysis consisted of investigating the relationship between driver characteristics, different vehicle size, and relative accident involvement. The number of accidents by vehicle weight were determined and normalized by car registration for the traditional method and number of accidents per innocent victim for the quasi-inducted method. The relationship for the quasi-induced exposure method was determined to provide a better fit than the results obtained by normalizing with the vehicle registration data. Using the induced exposure method the authors determined that the relationship between driver age and accident involvement was strong, regardless of the vehicle category with younger and older drivers involved more often than middle-age drivers. Their conclusions, plus the results of others, led them to believe that the quasi-induced exposure method holds considerable promise and relatively good accuracy.[36,37,38,39]

The second possiblity (that the traditional methods do not yield accurate results) is difficult to determine. To illustrate, however, consider two innocent drivers on a stretch of roadway. Imagine that one driver travels for 10 miles at 30 miles per hour, and the second driver travels for 20 miles at 60 miles per hour. Further imagine that for each 10-mile stretch of roadway there is a potentially guilty driver waiting to ambush the innocent vehicles. The guilty drivers will be successful in impacting an innocent vehicle if the innocent vehicles occupy a certain small interval of space within a particular small interval of time. In this example, since one vehicle is traveling at twice the speed, but twice the distance, the probability of each of these innocent vehicles getting into an accident would be the same. The traditional mileage-rate method of determining exposure results in the vehicle which is traveling twice as far having twice the probability of being in an accident. The use of vehicle miles traveled, therefore, to indicate exposure, from the point of view of crash opportunities, has the inherent assumption that vehicle speed is essentially equal for the different groups of drivers or vehicles being studied. The quasi-induced exposure method has assumptions which may result in exposure estimates that differ from those which would be obtained by using traditional mileage-rate methods.

PROJECT SCOPE AND METHODOLOGY

State and local highway agencies were contacted to determine the type and quantity of accident and operational data maintained by their agencies. Of particular concern were the data items determined to be of need in a comprehensive analysis of heavy truck accidents. The contacts established the accident and operational characteristics summarized below:

- Computerized accident summaries capable of identifying accidents by vehicle type.
- Copies of the original accident report form for at least 4 years.
- Capability of identifying the perceived most responsible driver for the accident.
- Ability to tentatively identify truck size from the computerized accident search.
- Detailed volume and percent truck mix counts.
- Log of urban freeway accidents including time of accident occurrence, lanes of freeway blocked and duration of disruption.
- Presence of urban freeway segments with bidirectional volumes greater than 100,000 vehicles per day and truck mixes greater than 5 percent.

The computerized summary of truck accidents were used to retrieve copies of the original accident reports. Information from copies of the original accident report were transcribed into a unique data file for analysis on a personal computer.

Over 400 accidents were selected from this data base and forwarded to the highway agency freeway surveillance unit for information to be used in a freeway delay model. Requested information included the flow rate at the time of the accident, bottleneck flow rate, number and duration of lane blockage and lapsed time until normal operation. The FHWA freeway delay model was used to estimate the average total delay per accident and the average delay per vehicle affected by the blockage.

Information on traffic volumes and truck mix were obtained from the respective roadway agencies. The truck mix data was supplemented by manual 24-hour counts to establish the validity of truck mix data.

CHAPTER 2 - ANALYSIS OF COMPARATIVE CHARACTERISTICS

The Transportation Department of various State and local agencies were contacted to determine the most appropriate freeway segments for project analysis. For freeway segments to be considered it was necessary that they had at least 100,000 vehicles per day and at least a 5 percent mix of truck traffic. Additional considerations that went into the segment selection criteria were: (1) availability of relatively accurate average daily traffic (ADT) and percent truck mix estimates, (2) the ability to provide computerized accident search and summary, and (3) the willingness to allow access to the original accident report records. These selection criteria resulted in the selection of four freeway segments from the Detroit, Michigan area, and one freeway segment from Seattle, Washington with a combined length of 46.5 miles.

The beginning and ending milepoints of the selected freeway segments were used as input into the computerized accident base of each study area. The computerized accident base was then used to generate: (1) a summary of characteristics for every accident that occurred, and (2) a listing of the individual truck accidents and the respective original accident report identifier. These data items were obtained for each selected urban freeway segment for the years 1985 through September 1988.

The computerized information on the characteristics of total accidents, including all vehicle types, was used for comparative purposes; as provided in subsequent sections of this report. The computerized information for truck accidents was used to locate and make copies of the original accident report for each truck accident identified as occurring on the analysis segments. The urban truck accident data base was developed directly from the original accident reports. A new data base was developed because: (1) it provided the data necessary to answer the unique questions of the urban truck project, (2) it combined the different data bases from each analysis State into a homogeneous data base, (3) it permitted the incorporation of strong quality control measures, thereby, eliminating any inadvertent keying errors on the original computerized

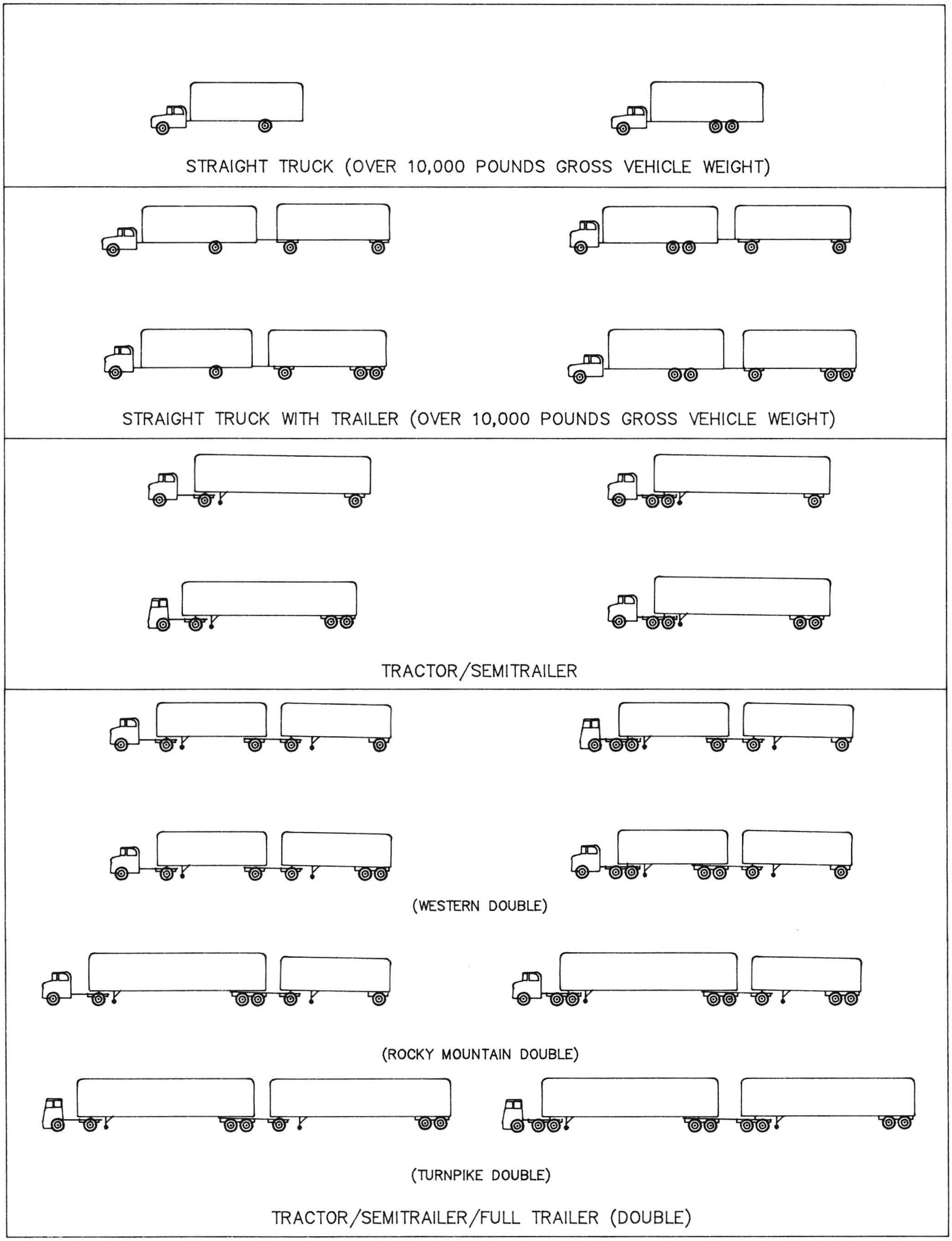


Figure 1. Truck configuration and respective terminology used for this report.

data base, and (4) it permitted the verification of truck type. The data from the original accident reports were coded onto computer forms and then double keyed into the urban truck accident data base.

The accidents were categorized by truck and trailer type. The major categories of truck were trucks over 10,000 lb gross vehicle weight, and tractor/trailer combinations. A description of the truck classifications used in this report are presented as figure 1. Verification of the truck type was accomplished by inspection of the vehicle identification number (VIN) for those year models 1982 and newer. In the absence of a VIN or for those model years which were older than 1982 (when vehicle identification numbers adhered to establish standards), vehicle verification was accomplished by the verbal description and/or by the diagram contained on the original accident report.

The method by which the truck type was verified was included in the accident data base. Those accidents whereby the vehicle type could not be verified, or were verified as not involving a truck, were excluded from the analysis. The original accident reports of 2,613 truck accidents were copied for this project. Of this total, 2,347 accidents were identified as either occurring on the freeway itself or on freeway ramps. The remaining 266 accidents were identified as occurring on surface streets in the vicinity of freeways. Of the 2,347 truck accidents occurring on freeways and freeway ramps, 2,221 were verified for project use. A summary of the verification results is presented as figure 2.

The truck and trailer combinations used in the analysis, and the respective accidents, are presented on table 3. A total of 491 straight trucks over 10,000 lb gross vehicle weight, and 1,730 tractor/trailer combinations were used in the analysis. Truck/tractors without trailers for this report are called bobtails. The breakdown of characteristics for the 33 bobtail accidents was not represented in all of the descriptive statistics contained in the following sections. The bobtail characteristics were not included because when the relatively small number of bobtail accidents where stratified by an analysis variable (i.e., day of week, weather conditions, etc.) the resultant accident frequencies were too small for meaningful conclusions.

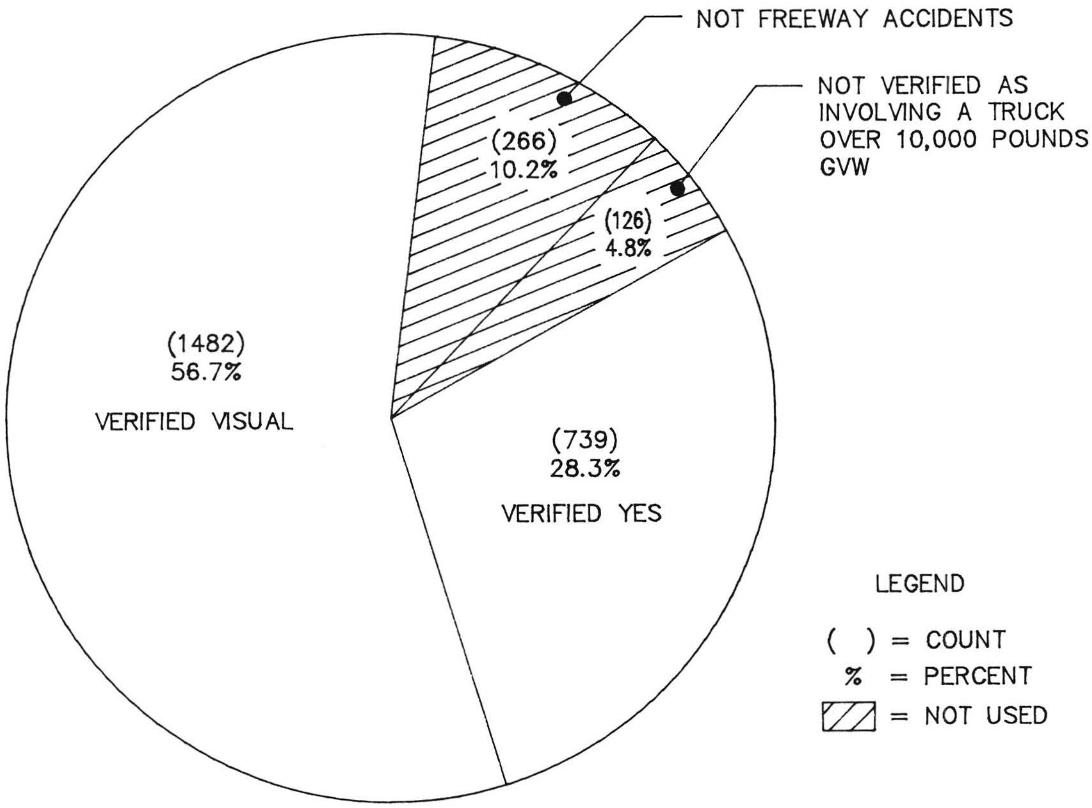


Figure 2. Summary of truck type verification.

Table 3. Verified accidents by truck and trailer type used in the analysis.

Truck Type	Number of Trailers: None	Number of Trailers: Single Trailer	Number of Trailers: Double Trailer	Row Totals
Straight Truck	323 (14.5)	168 (7.6)	-	491
Truck Tractor	33 (1.5)	1,605 (72.3)	92 (4.1)	1,730
Column Totals	356	1,773	92	2,221

( ) represents percent of total

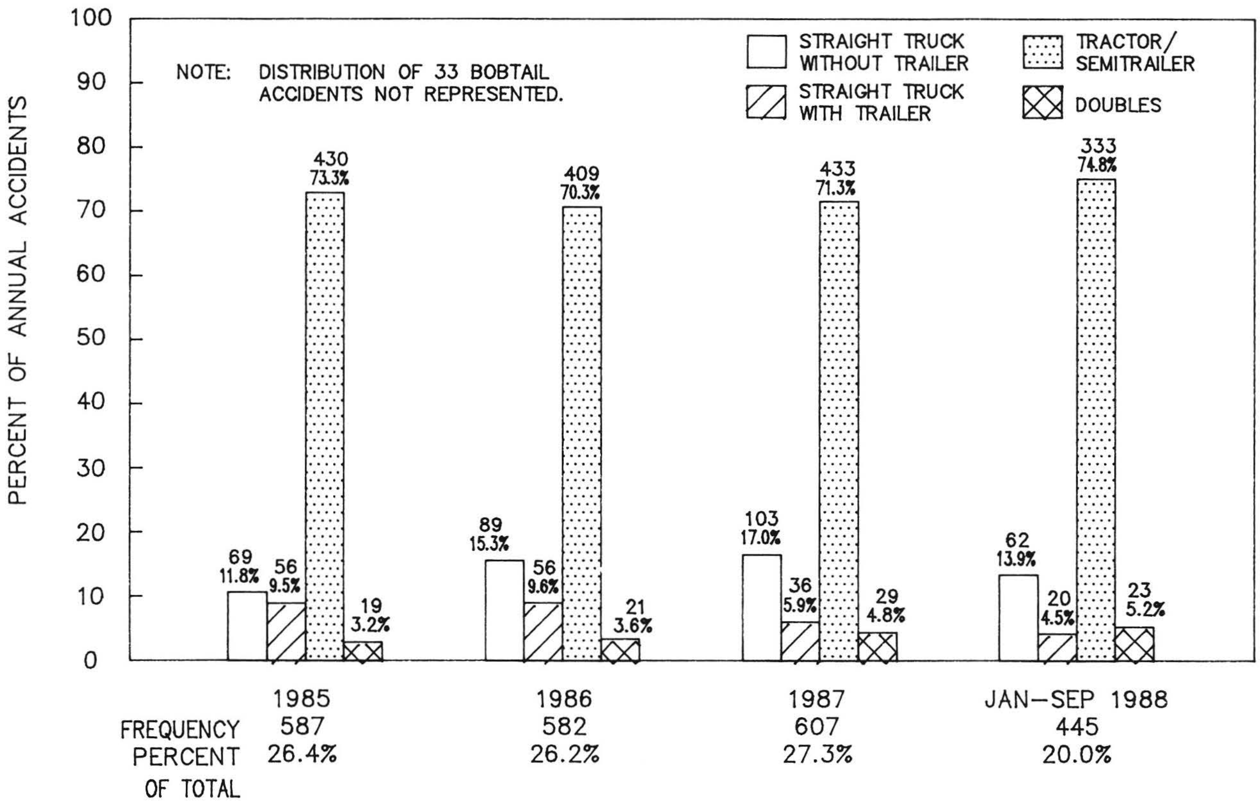


Figure 3. Distribution of truck accidents by year of analysis and the relative share of annual accident totals by truck/trailer combination type.

DISTRIBUTION OF TRUCK ACCIDENTS BY TIME

The distribution of truck accidents by year from 1985 through September of 1988 is presented as figure 3. The annual occurrence of truck accidents is relatively consistent with each year contributing approximately 26 to 27 percent of the accidents being analyzed. The only exception is 1988 which accounted for 20 percent of the total accidents but only consisted of 9 months of data. Doubles accidents experienced an increasing percentage of the annual truck accident occurrence with the smallest percentage (3.2 percent) occurring during 1985 and the highest percentage (5.2 percent) during 1987. Straight trucks without trailers also exhibited an increasing percentage of annual accidents from 1985 through 1987.

Accident occurrence by quarter of the year, presented as figure 4, remained relatively consistent. The only exception was the fourth quarter (i.e., October, November and December), during which approximately 29 percent of the truck accidents occurred, as opposed to the 23.6 to 25.1 percent occurrence of the other annual quarters. Straight trucks and tractor/semitrailers displayed the largest increase in accidents during the fourth quarter. The quarterly summary of accidents presented in figure 4 excludes the 445 accidents occurring during 1988 since that analysis year did not contain accidents occurring during the fourth quarter.

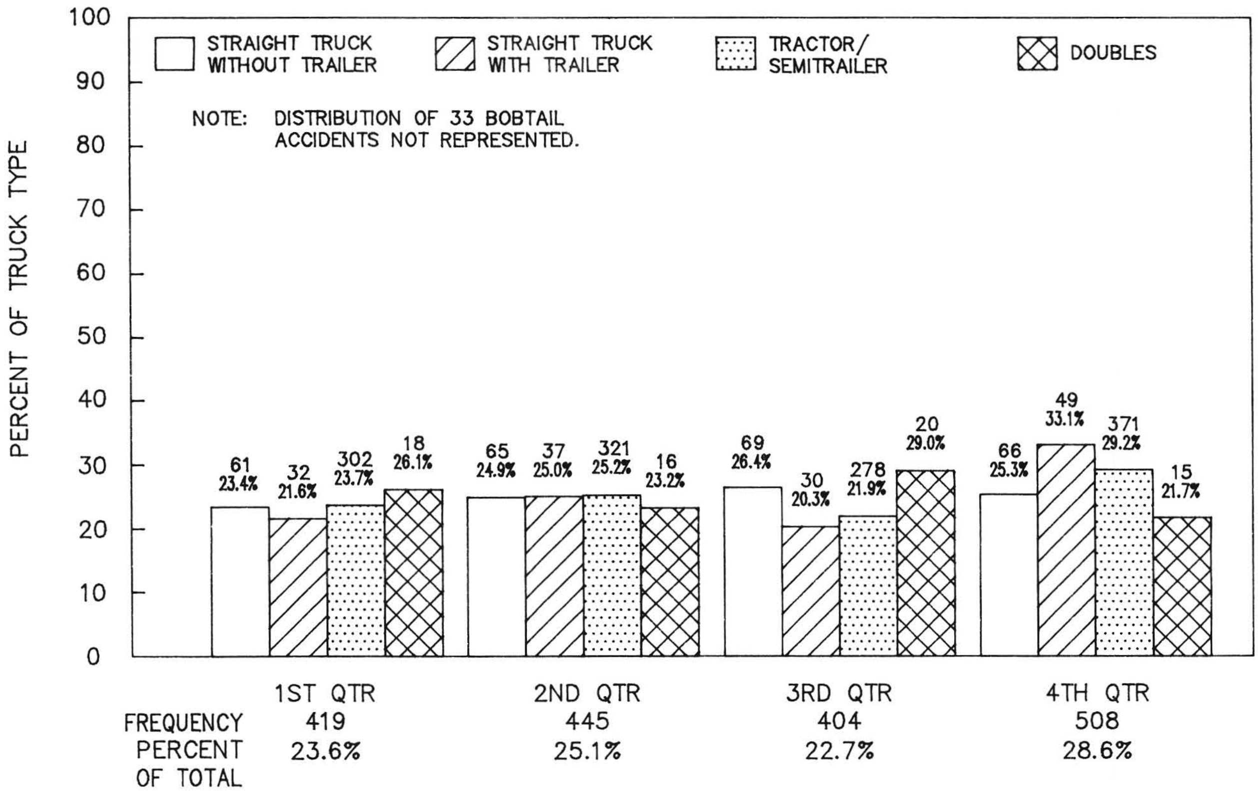


Figure 4. Distribution of truck/trailer combination type and total truck accidents by quarter of the year (excluding the 445 accidents of 1988).

The distribution of accidents by the day of the week, presented as figure 5, indicates that more accidents occurred on Friday than any other day for all types of trucks combined. The greatest percentage of accidents involving tractor/semitrailers also occurred on Fridays. A larger percentage of straight truck accidents occurred on Saturdays and Sundays than any other truck type.

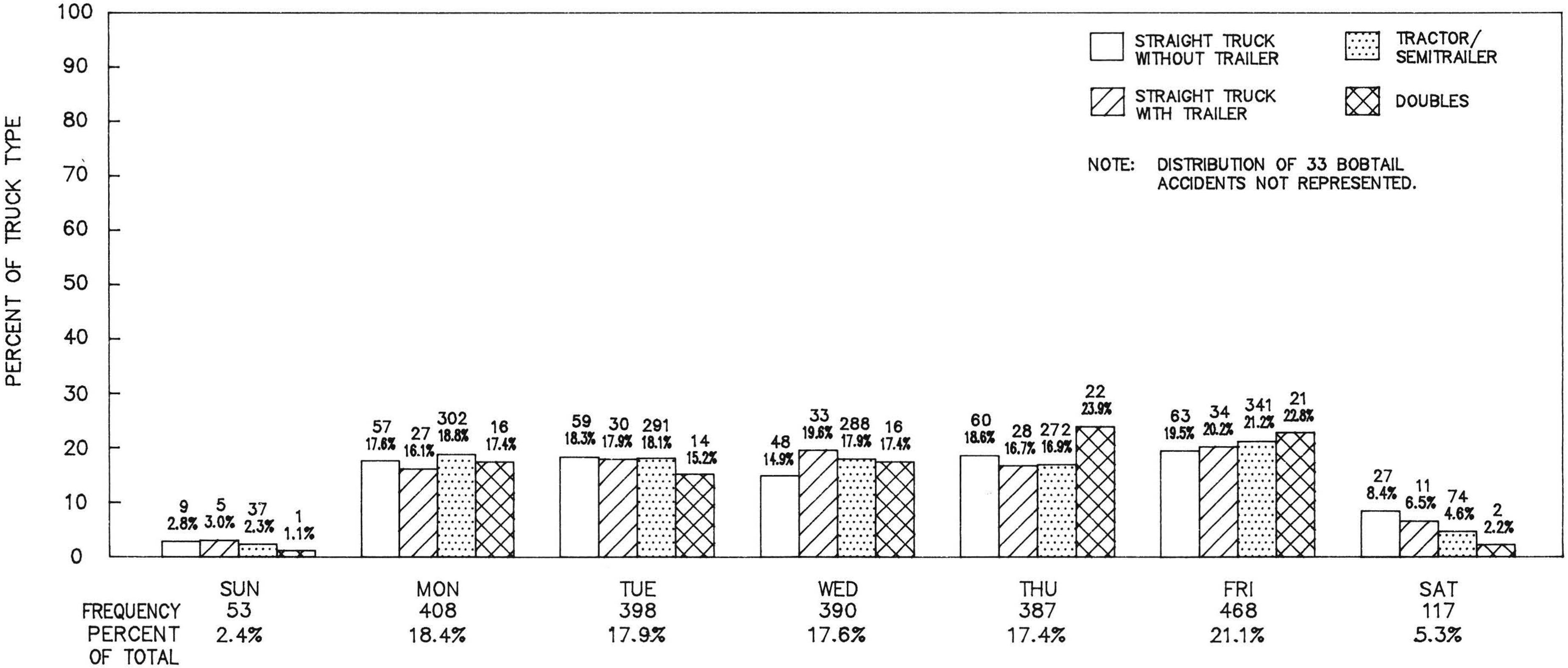


Figure 5. Distribution of truck-trailer combination type and total truck accidents by day of week.

The distribution of truck accidents by time of the day is presented in figure 6. The largest percentage of truck accidents occurred from noon to 6:00 p.m. (48.6 percent). The second highest percentage of accidents occurred between 6:00 a.m. and noon (33.7 percent). The percentage of doubles accidents occurring in two separate time periods; from 6:00 a.m. to noon and from 6:00 p.m. to midnight, exceed the similar timeframe accident percentage of any other truck category. Approximately 50 percent of the straight truck and tractor/semitrailer accidents occurred between noon and 6:00 p.m.

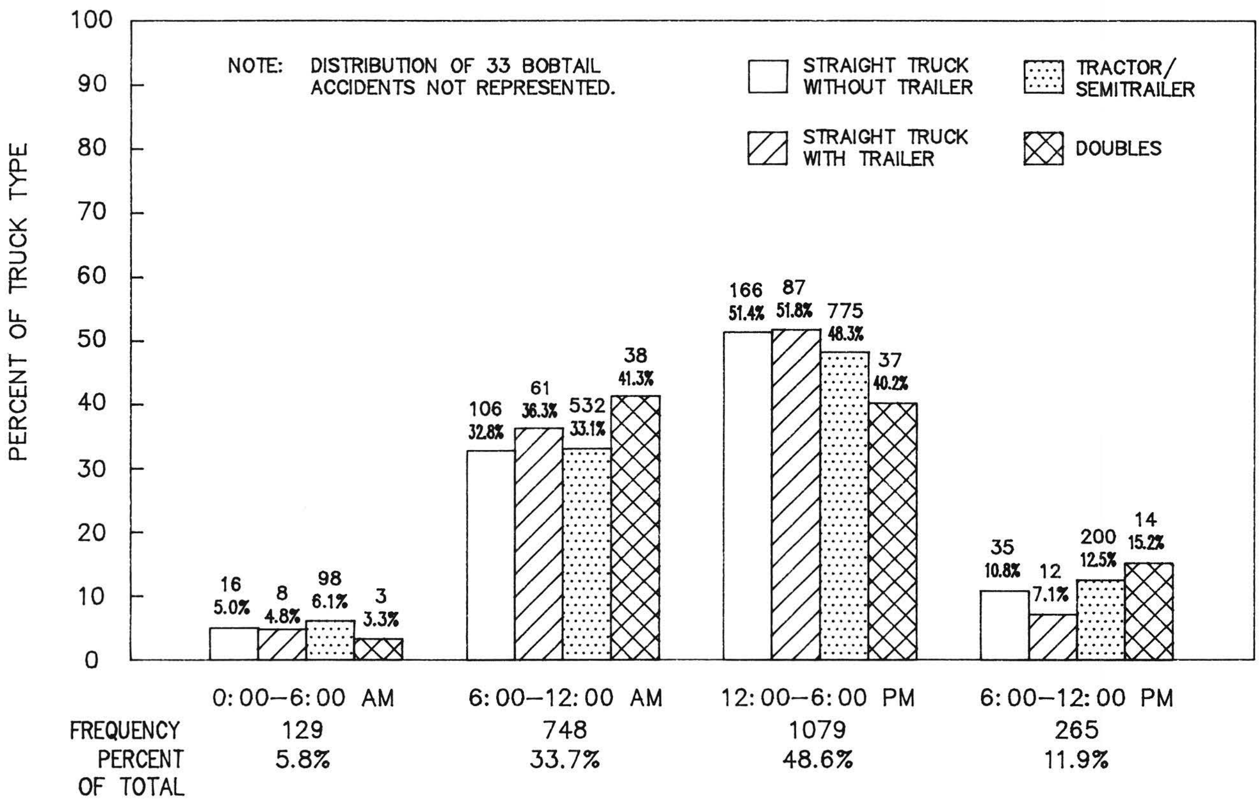


Figure 6. Distribution of truck/trailer combination type and total truck accidents by time of day.

TRUCK ACCIDENTS STRATIFIED BY ENVIRONMENTAL AND ROAD CONDITIONS

Accident occurrences by weather conditions, present during the time of the accident for different combinations of truck and trailer type, are presented as figure 7. As expected, the largest percentage of truck accidents occurred during clear or cloudy conditions (78.2 percent) due to prevalent weather patterns. The accidents experienced by different combinations of truck and trailer type remained relatively constant within each category of weather condition. Straight trucks with trailers experienced a greater percentage (23.8 percent) of their accidents occurring during rainy weather conditions than any other truck/trailer type.

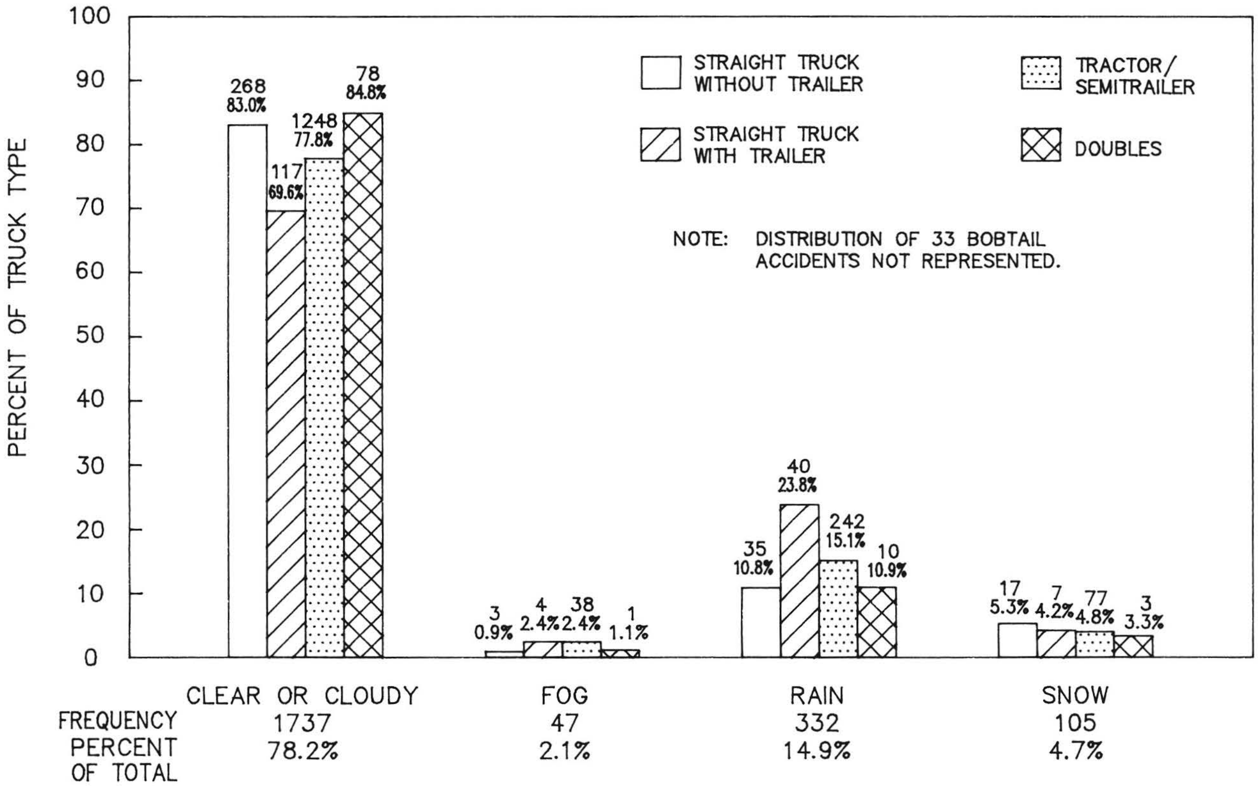


Figure 7. Distribution of truck/trailer combination type and total truck accidents by weather conditions.

The distribution of truck accidents by road surface conditions, presented as figure 8, parallels the weather condition accident experience. Straight trucks with trailers experienced 32.7 percent of their accidents during wet road conditions. This exceeds the wet road surface accident experience of any other truck/trailer combination. Straight trucks with trailers, therefore, appear to exhibit a greater accident potential during wet road conditions than any other tractor/trailer combination type.

Daytime conditions were present during 79.3 percent of all the accidents involving a truck, 16.4 percent at night and 4.3 percent during dawn or dusk conditions, as presented by figure 9. Straight trucks with trailers exhibited the smallest percentage (9.7 percent) of their accidents occurring during nighttime and the largest percentage (86.3 percent) during the daytime. The occurrence of accidents by different light conditions was relatively consistent among the different combinations of truck and trailer types.

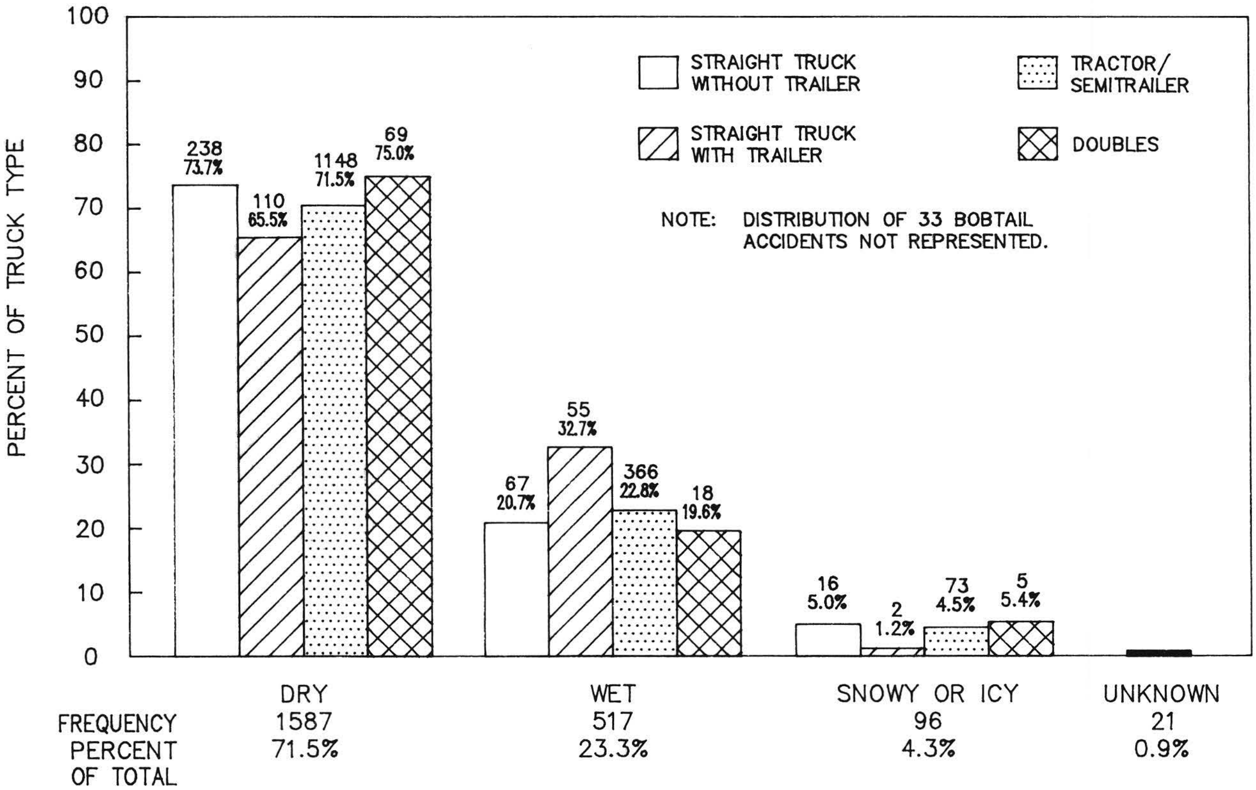


Figure 8. Distribution of truck/trailer combination type and total truck accidents by road surface conditions.

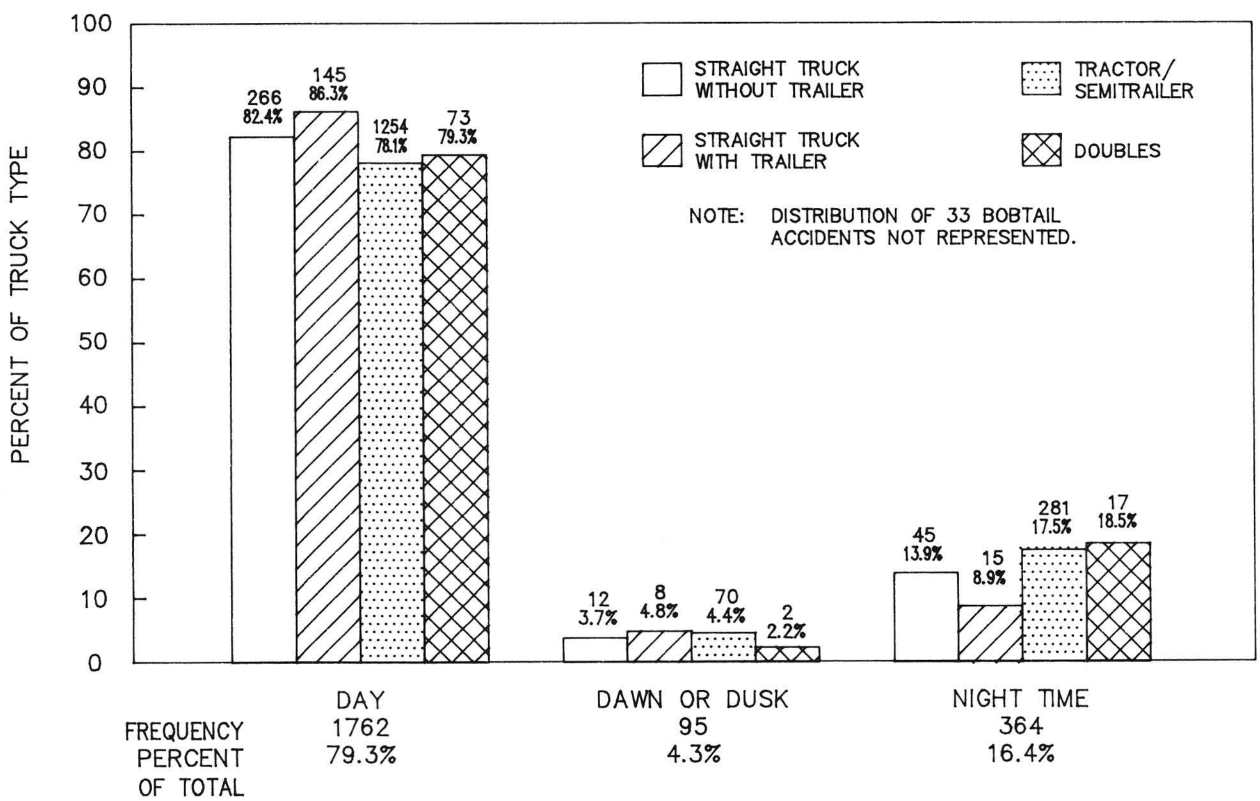


Figure 9. Distribution of truck/trailer combination type and total truck accidents by light conditions.

ADDITIONAL TRUCK ACCIDENT CHARACTERISTICS

The total number of other vehicles involved in each truck accident is presented as figure 10. The majority of all the investigated accidents (73.4 percent) involved one other vehicle in addition to the truck. The distribution of accidents by combinations of truck/trailer types was relatively constant between the groups of involved vehicles.

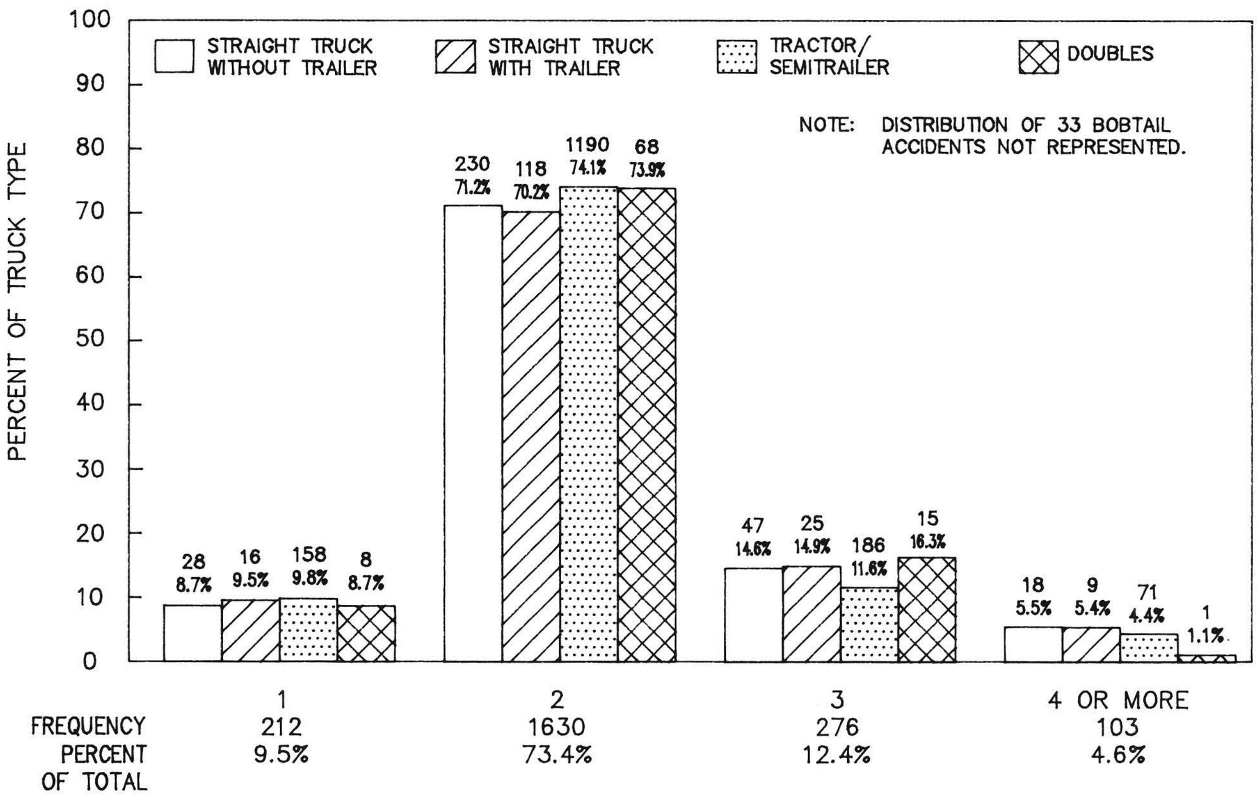


Figure 10. Total number of vehicles involved in individual truck accidents by truck/trailer combination type and total truck accidents.

Figure 11 presents the breakdown of the 103 accidents that involved a total of 4 or more vehicles. Tractor/semitrailers were involved in 68.9 percent of the 4 or more vehicle accidents which involved a total of 326 vehicles; with 1 accident involving 16 vehicles. Straight trucks without trailers accounted for 17.5 percent of all the accidents involving 4 or more vehicles. A total of 81 vehicles were involved in these straight-truck accidents; the largest accident of which included 7 vehicles.

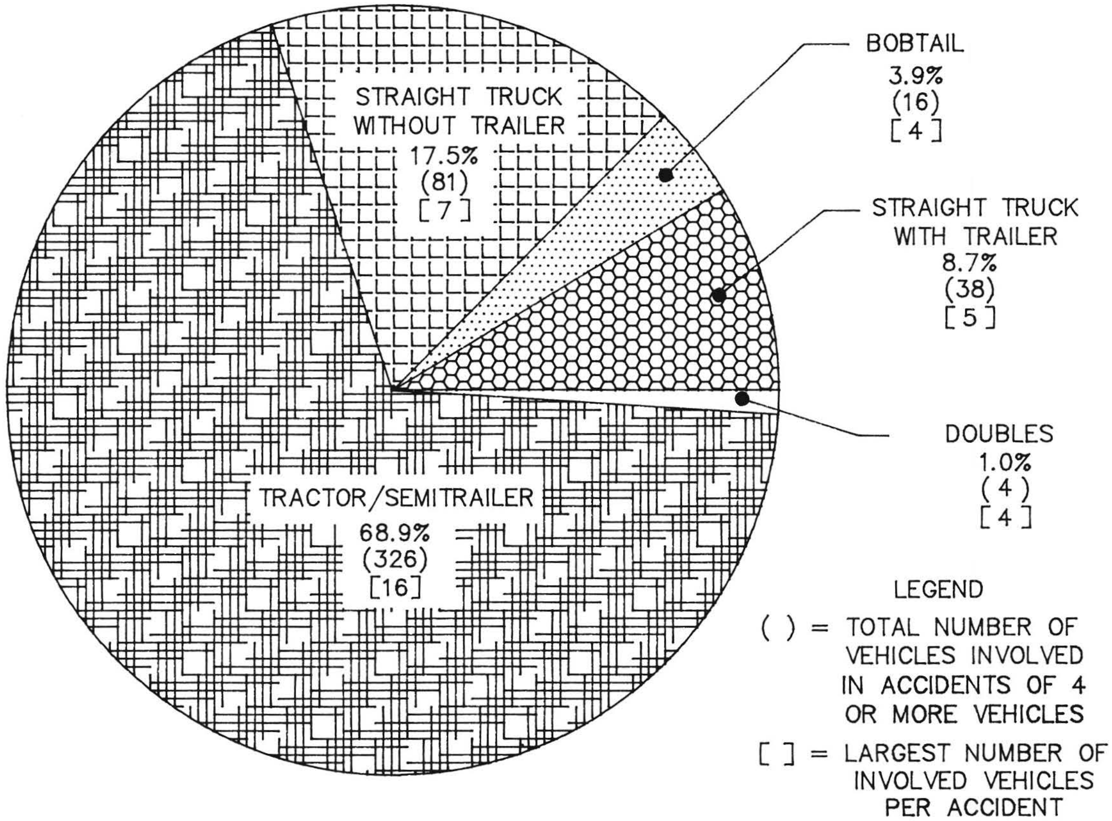


Figure 11. Distribution of accidents involving a total of 4 or more vehicles by truck and trailer type.

A total of 4,765 vehicles were involved in the investigated accidents, consisting of the 2,221 truck/trailer types identified for analyses (primary truck/trailer type) and 2,544 other vehicles. Figure 12 presents the involved vehicles by type, excluding the primary truck-trailer combination type. For example, there were 89 tractor/semitrailers and 63 straight trucks involved in the accidents, in addition to the primary truck/trailer types identified for analysis.

Figure 13 indicates that 642 out-of-State and 1,404 in-State truck drivers were involved in the analyzed accidents. The police responded to and completed the accident reports for 1,792 of the investigated cases. Drivers of either the truck or other involved vehicles completed the accident reports at a police station in 429 of the cases. The driver-completed reports typically involved low property damage or hit-and-run occurrences. In those instances where the truck driver was the hit-and-run offender, the reporting driver stated in the accident descriptions that the truck drivers probably had not known that an accident occurred.

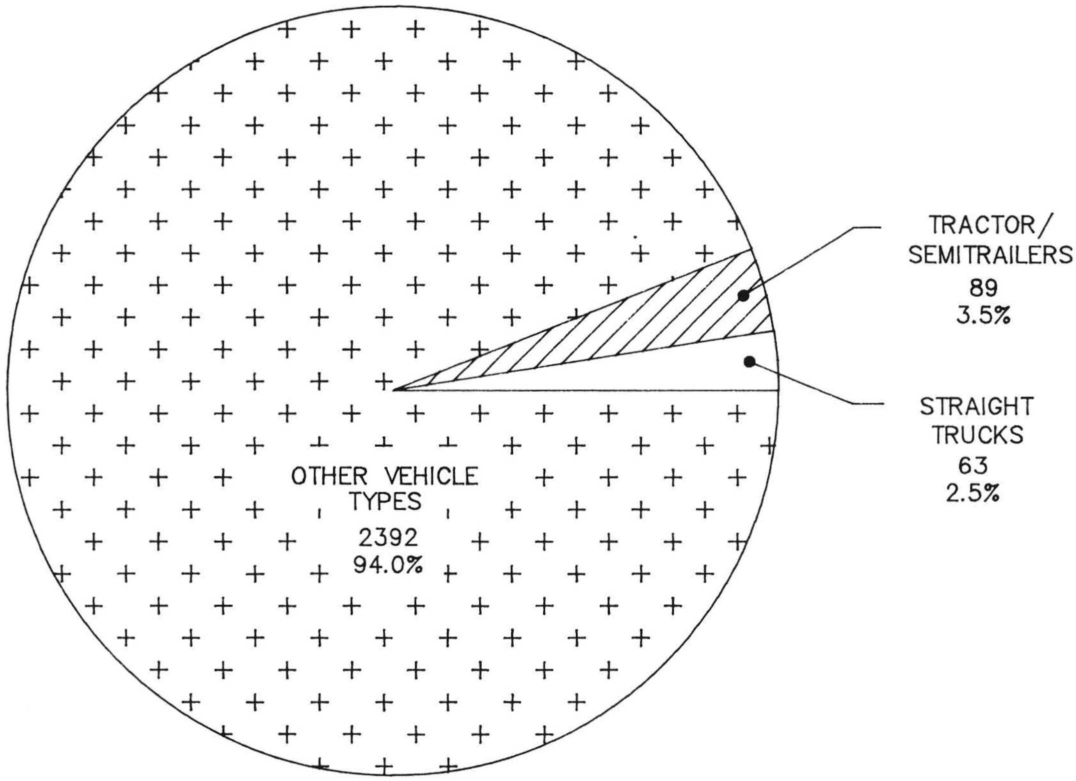


Figure 12. Number and type of vehicles involved in truck accidents (excluding the primary truck/trailer combination type).

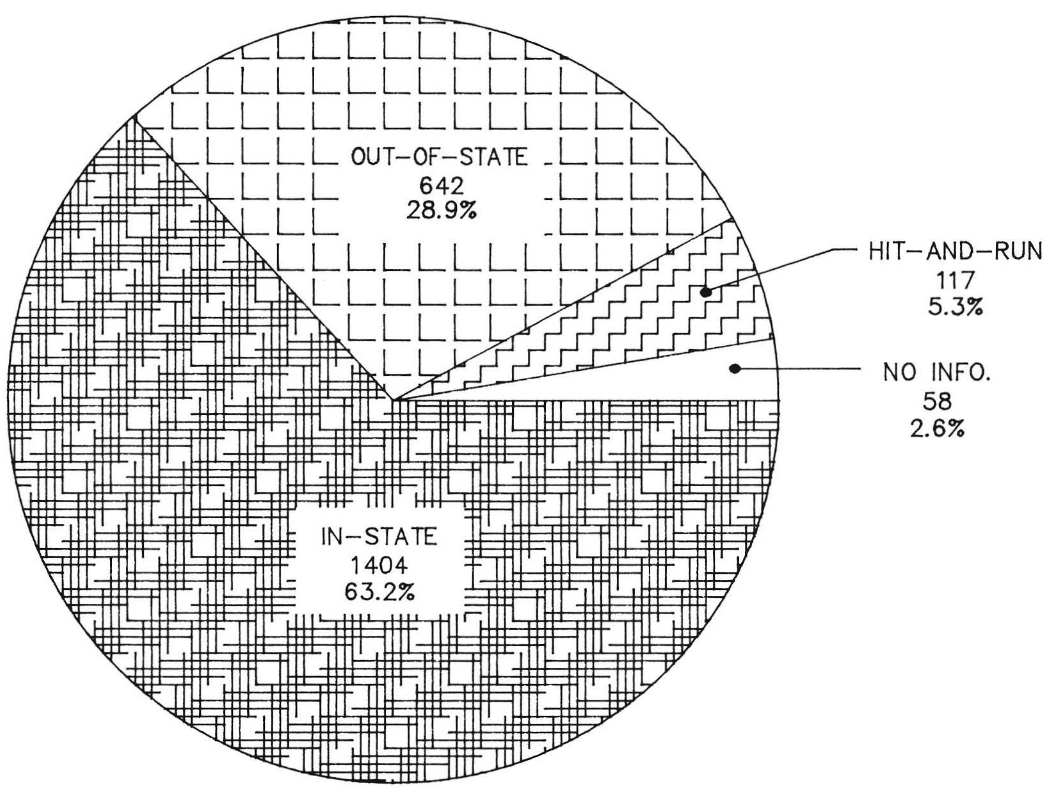


Figure 13. Registration of truck drivers involved in accidents.

Figure 14 presents the hazardous action attributed to the truck driver as being the probable cause of the accident. Truck drivers were found to be not at fault in 50.4 percent of the accidents investigated. Where the truck driver was cited as performing a hazardous action which led directly to the accident, the most common actions were: improper lane use (15.9 percent); following too close (13.6 percent); and speed too fast for conditions (8.1 percent). The majority of those cases where the truck drivers were cited for improper lane use were usually the direct result of changing lanes to the right when the adjacent lane was occupied. Tractor/semitrailers and doubles had the highest proportion of accidents attributable to improper lane change of any truck/trailer type. Straight trucks had the highest proportion of accidents attributable to following too close. Only 11 (0.5 percent) of the truck accidents involved the consumption of alcoholic substances by the truck driver.

Figure 15 indicates that 37.9 percent of the truck drivers involved in the analyzed accidents were in the age group of 25 to 35. The second largest age group represented was from 36 to 46 which accounted for 28.4 percent of the investigated accidents. Straight trucks, both with and without trailers, had the largest percentage of accidents involving truck drivers in the youngest age group of 17 to 24 years.

The right front of the truck was the first point of impact in 29.2 percent of the accidents, as presented in figure 16. The second point of most frequent impact on the trucks was the front center, which accounted for 24.2 percent of the investigated accidents. Tractor/semitrailers and doubles accidents had 32.9 percent and 20.7 percent, respectively, occurring with the right front as the first point of impact. This point of impact can be correlated to the fact that the largest number of hazardous actions attributable to these truck types were improper lane use. The right front of the trucks corresponds to that portion of the vehicle which has a blind spot when the truck driver is changing lanes to the right.

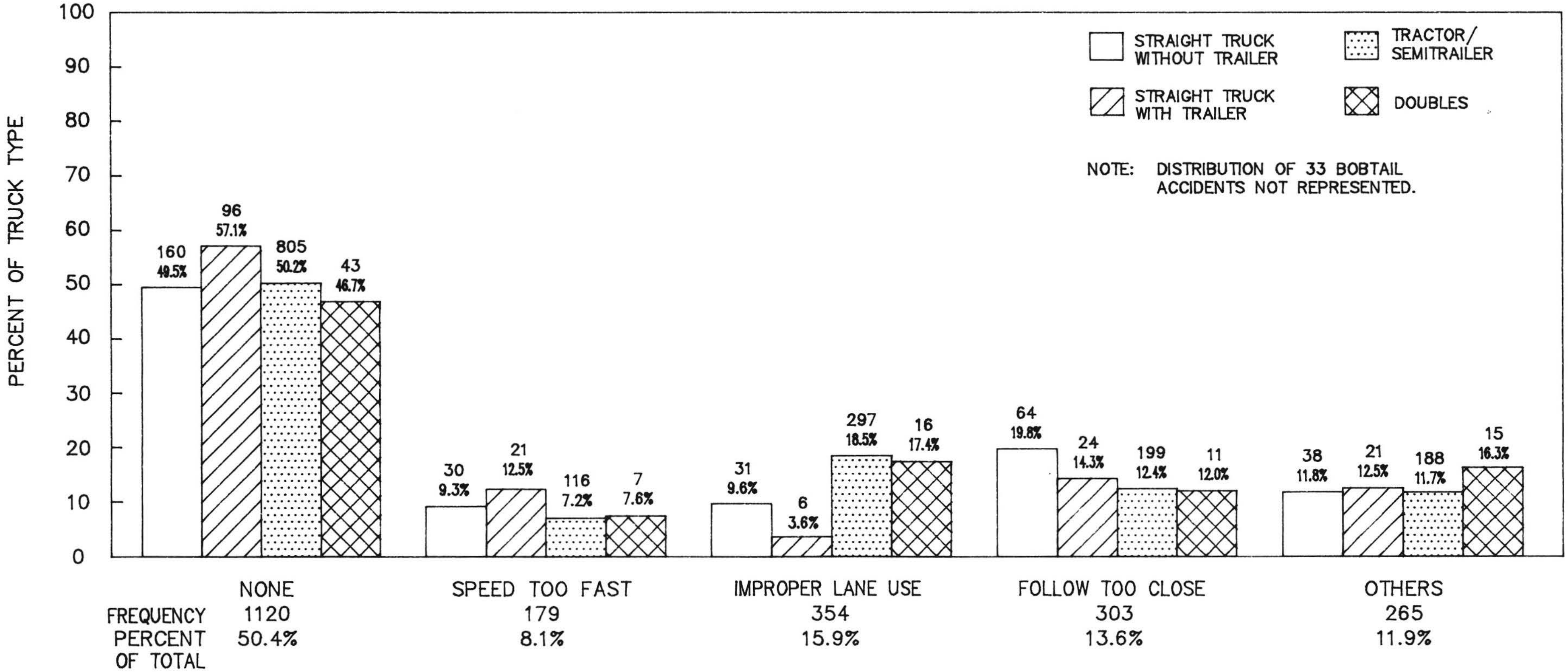


Figure 14. Hazardous action attributable to truck drivers.

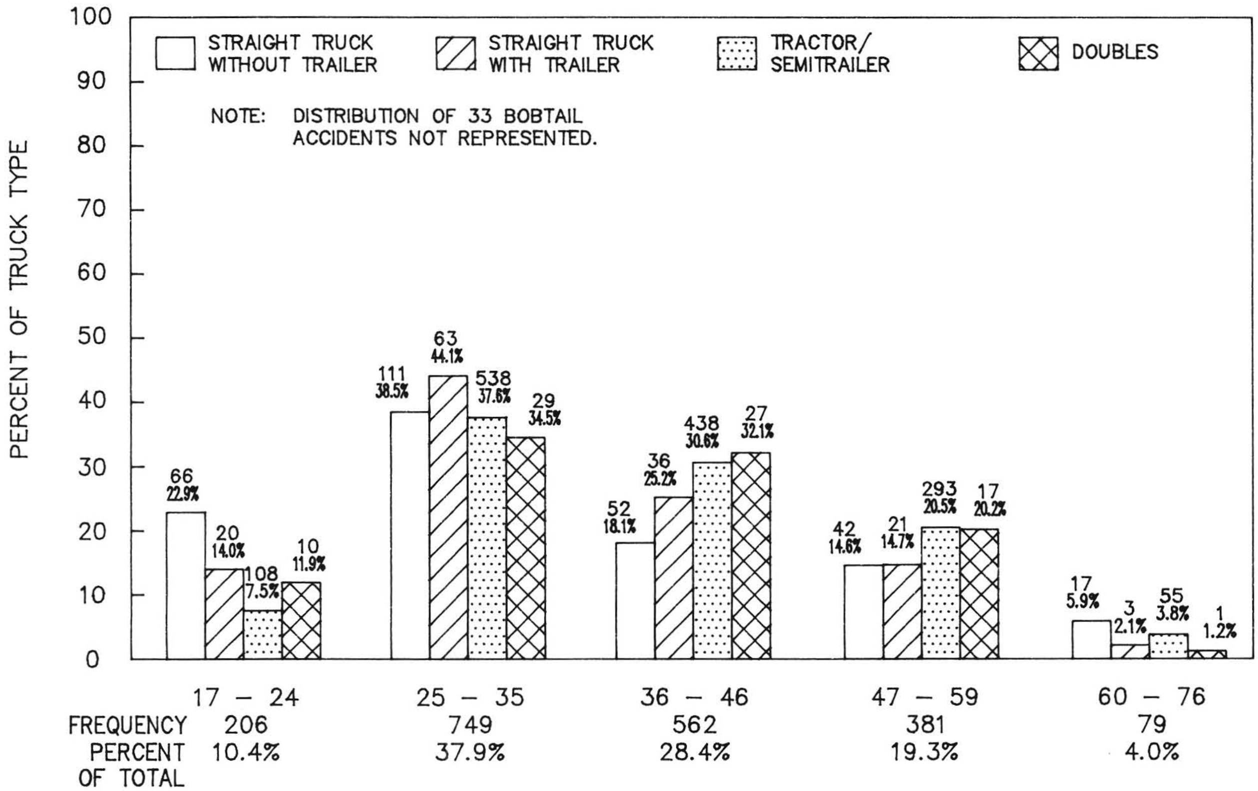


Figure 15. Distribution of truck driver age by truck/trailer combination type and total truck accidents.

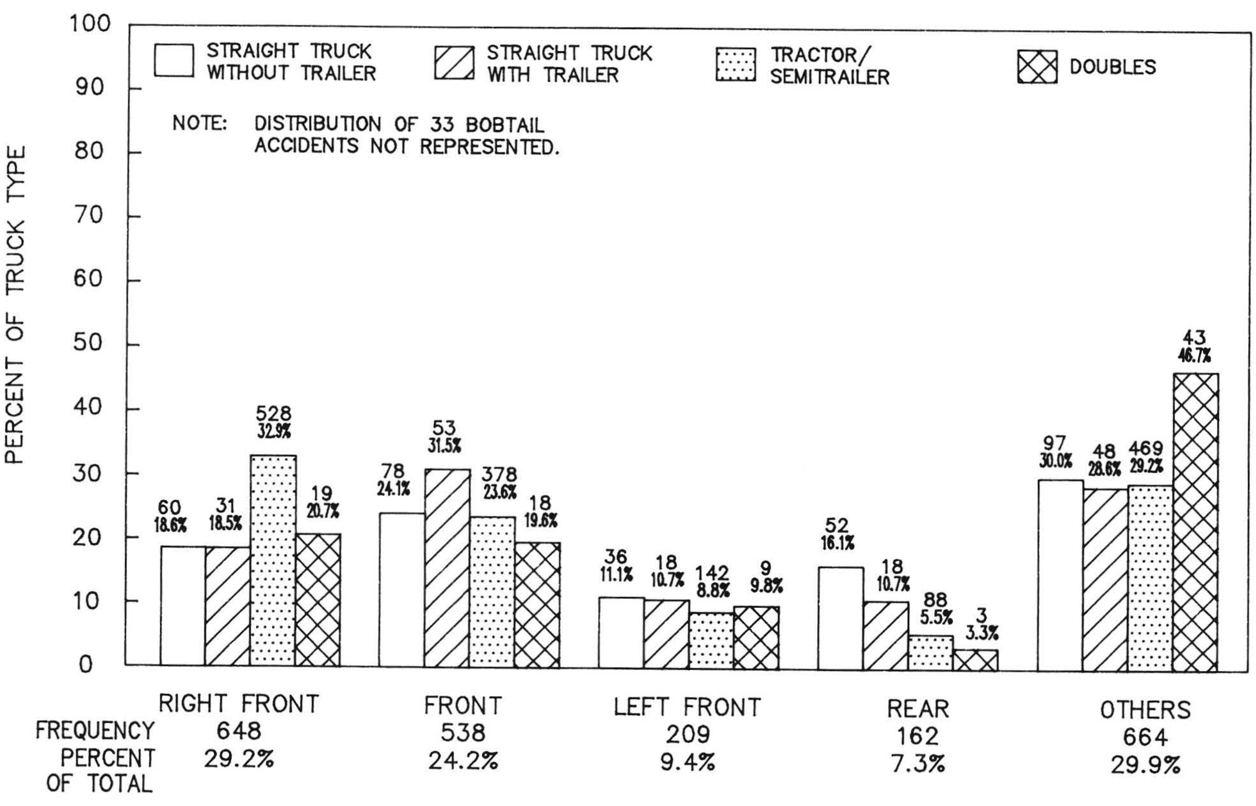


Figure 16. Portion of truck first impacted during accident by truck/trailer combination type and total truck accidents.

Figure 17 presents the number and percentage of times, by truck-trailer type, that cargo spillage, fuel leakage and vehicle fire occurred. Cargo spillage occurred in 114 of the 2,221 accidents (5.1 percent). Tractor/semitrailers had the greatest incidence (66.7 percent) of the cargo spillage accidents. Tractor/semitrailers were also the greatest contributers to incidents of fuel leakage and vehicle fire, although, both of these occurrences were relatively rare. The type of cargo being hauled at the time of the accident was in the majority of cases unrecorded on the accident form. For those instances where the cargo was recorded, the largest number of accidents occurred when the vehicle was empty. Accidents occurred when 9.6 percent of the tractor/semitrailers and 12.0 percent of doubles were empty.

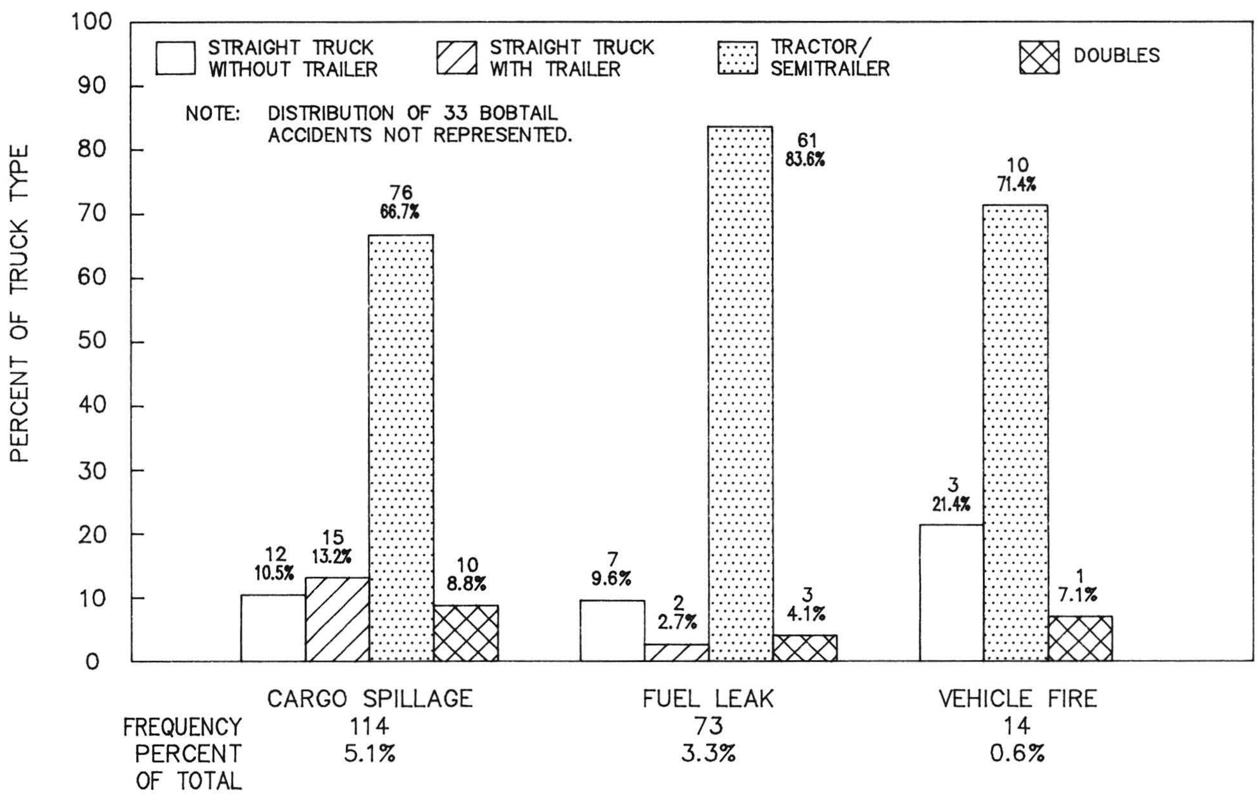


Figure 17. Percentage of indicated incidents occurring by truck/trailer combination type and total truck accidents.

The most predominant types of truck accidents are summarized in figure 18. Sideswipes accounted for 48.8 percent, rear-ends for 28.5 percent, and fixed-object for 5.3 percent of all the truck accidents investigated. Tractor/semitrailers and doubles had over 50 percent of their accidents occur as sideswipes. The largest proportion of straight-truck accidents occurred as rear-end accidents.

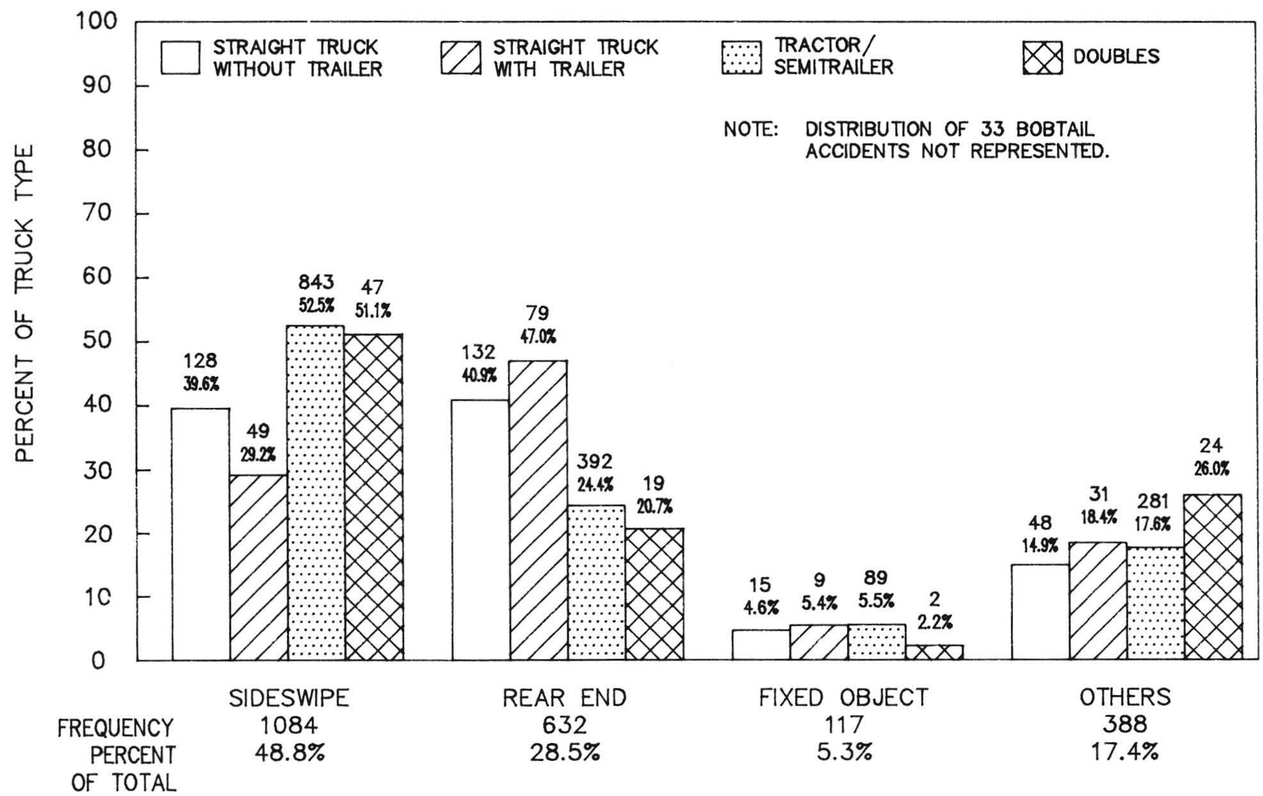


Figure 18. Distribution of accident type by truck/trailer combination type and total truck accidents.

Figure 19 presents the distribution of the primary accident types by the portion of the truck that was first impacted. Sideswipe accidents predominantly occurred with impact on the right side of the truck (61.7 percent) with the left side of the truck being involved in 25.5 percent of the sideswipe accidents. In the majority of rear-end accidents (66.9 percent) it was the front of the truck that impacted the rear of the other vehicle. In only 29.4 percent of the accidents were the rear end of the trucks impacted.

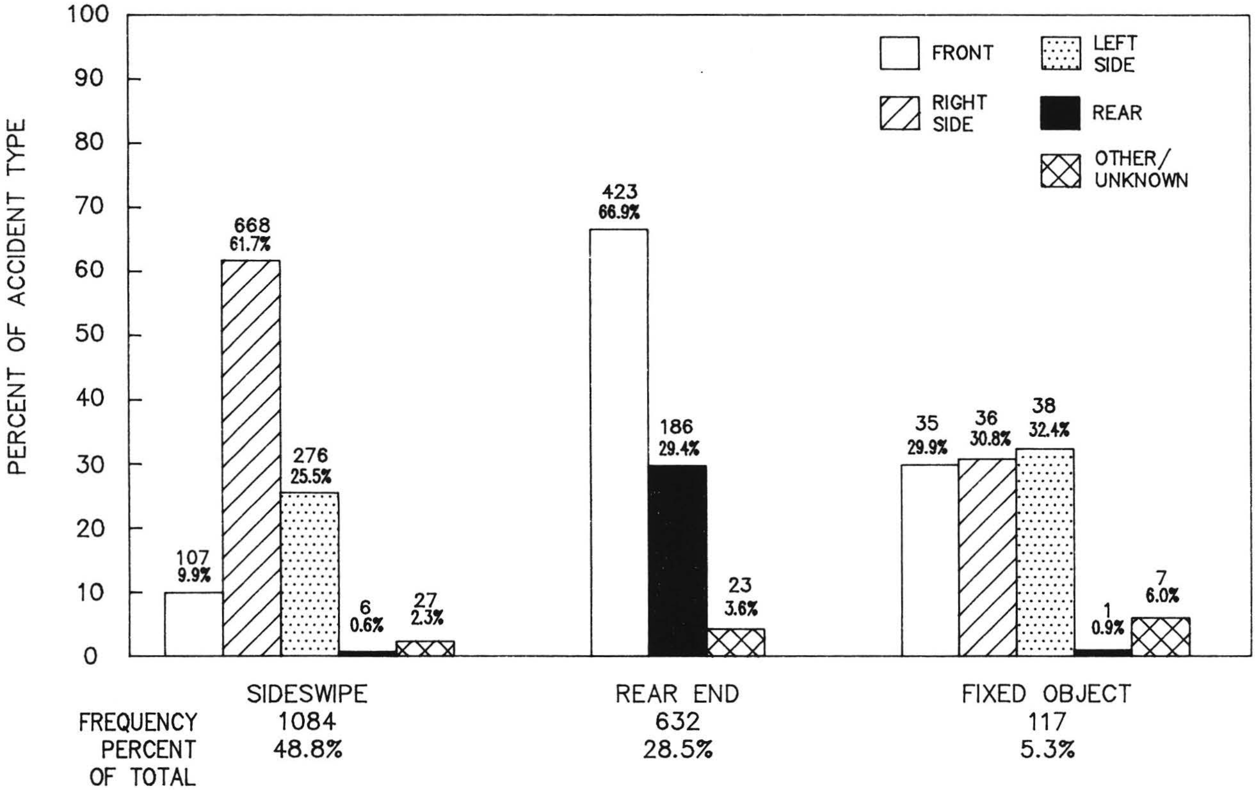


Figure 19. Distribution of accident type by truck impact point.

An inspection of the predominant accident types by truck driver action immediately prior to the accident is presented in figure 20. The majority of sideswipe accidents occurred when the truck driver was changing lanes (51.9 percent), 5.0 percent when the truck driver was attempting to merge or exit the freeway, and 38.7 percent when the truck was going straight and other vehicles impacted the truck. The majority of fixed object accidents (55.5 percent) occurred when the truck driver had lost control of the truck.

ACCIDENT ANALYSIS BY FREEWAY AREA

The freeway areas in the proximity of which an accident occurred was made a part of the urban truck file. If the pictorial accident representation contained on copies of the original accident report indicated a ramp or if the verbal description mentioned movement to or from a ramp then the appropriate freeway area was designated in the urban truck file. The results were freeway area designations of freeway proper, right-hand merge/exit, left-hand merge/exit, and ramp proper areas. The accident locating capability of the accident reports was not sufficiently accurate to define merge and exit areas as a specified distance upstream and downstream from the ramps. The designation of merge and exit areas is, therefore, somewhat arbitrary.

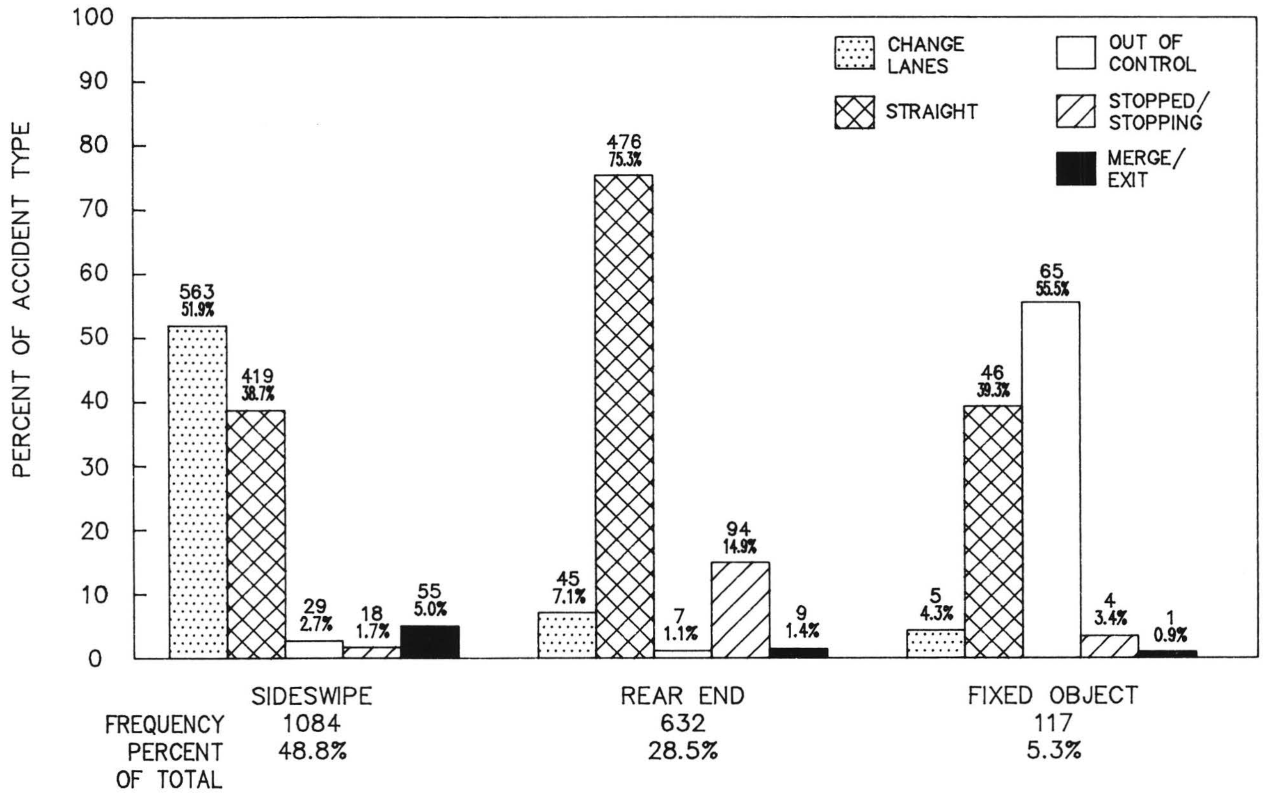


Figure 20. Distribution of accident type by truck driver action immediately prior to the accident.

A summary of truck accident occurrence by freeway area is presented as figure 21. The majority of truck accidents occurred on the freeway proper (76.9 percent) and removed from merge and exit ramps. The distribution of accidents by truck/trailer combination types was relatively constant within each freeway area. No particular truck/trailer combination, therefore, experienced a greater percentage of accidents within a particular type of freeway area.

Figure 22 presents the distribution of accident type by freeway area. Sideswipe accidents occurred in right-hand merge areas 13.1 percent of the time. Rear-end accidents occurred on the ramps proper (i.e., none of the vehicles involved in the accident were on the freeway itself) 5.5 percent, while 66.7 percent of the fixed-object accidents occurred on the freeway away from merge and exit areas.

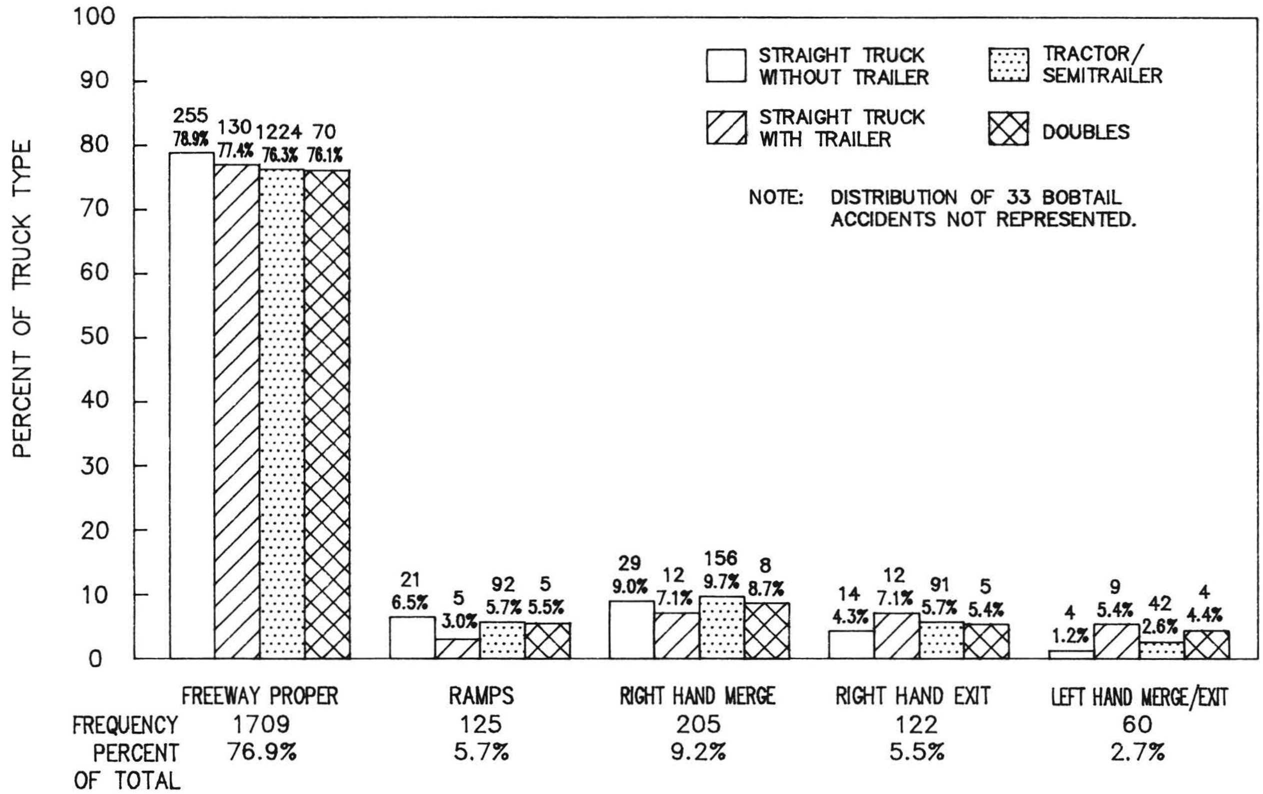


Figure 21. Distribution of truck/trailer combination type and total truck accidents by freeway area.

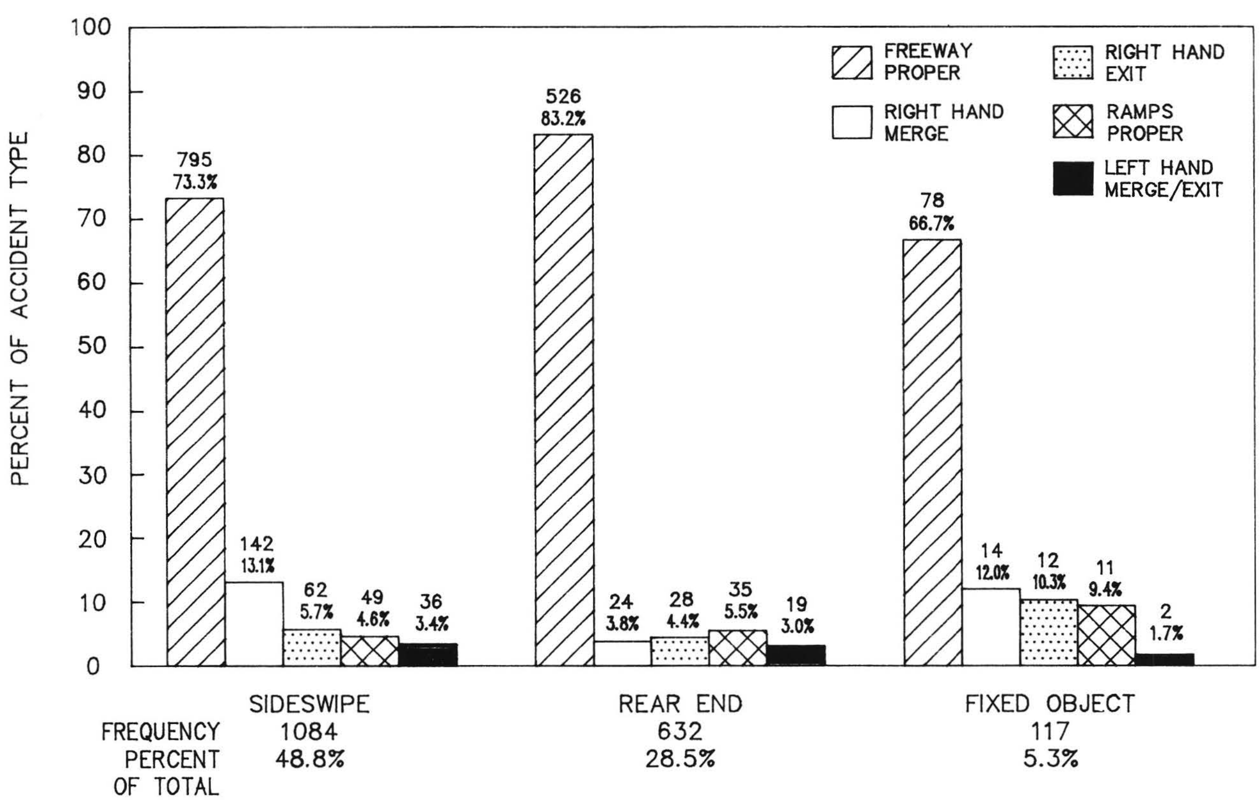


Figure 22. Distribution of predominant accident types by freeway area.

Figure 23 presents the distribution of freeway area accidents when the truck was occupying a lane of the freeway. During the 205 accidents, which occurred in a right-hand merge area (from figure 21), the truck was on the freeway in 186 (90.7 percent) of the cases (from figure 23). Similarly, for those accidents which occurred in a right-hand exit area of the freeway the truck was on the freeway in 73.0 percent of the cases. This indicates that the truck was not the vehicle performing the merge maneuver when the merge accident occurred.

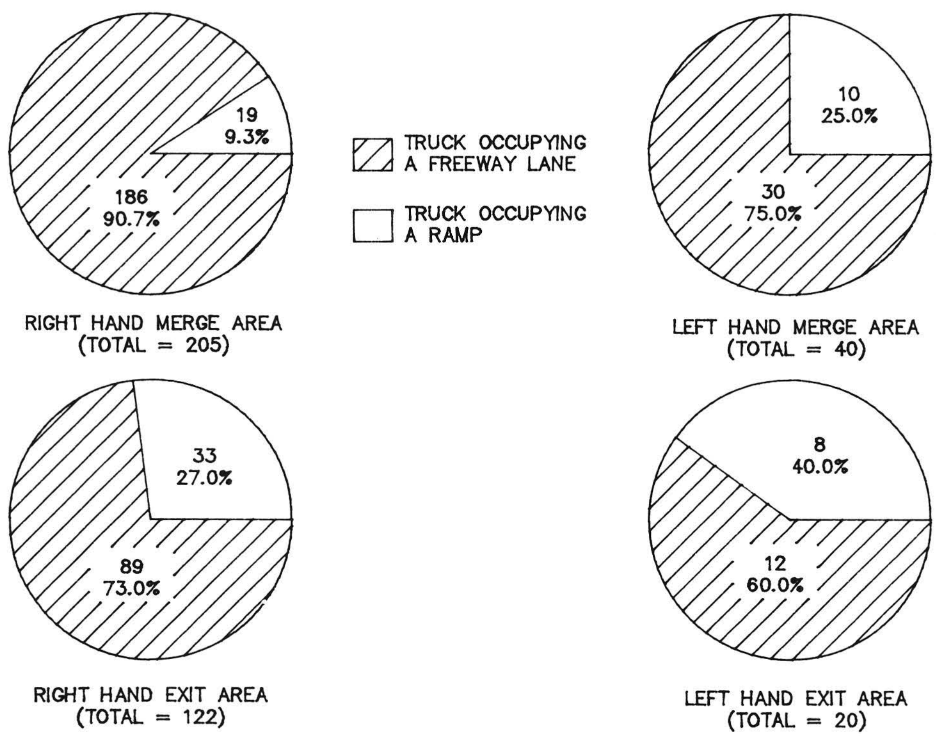


Figure 23. Percentage of trucks occupying the freeway proper during ramp area accidents (i.e., trucks not performing the exit or merge maneuver).

Figure 24 presents the freeway lane occupied by the truck immediately prior to the accident. The majority of truck accidents occurred with the truck occupying the second lane (35.7 percent) from the right-hand road edge. The largest majority of merging accidents occurred when the truck occupied the first right-hand lane.

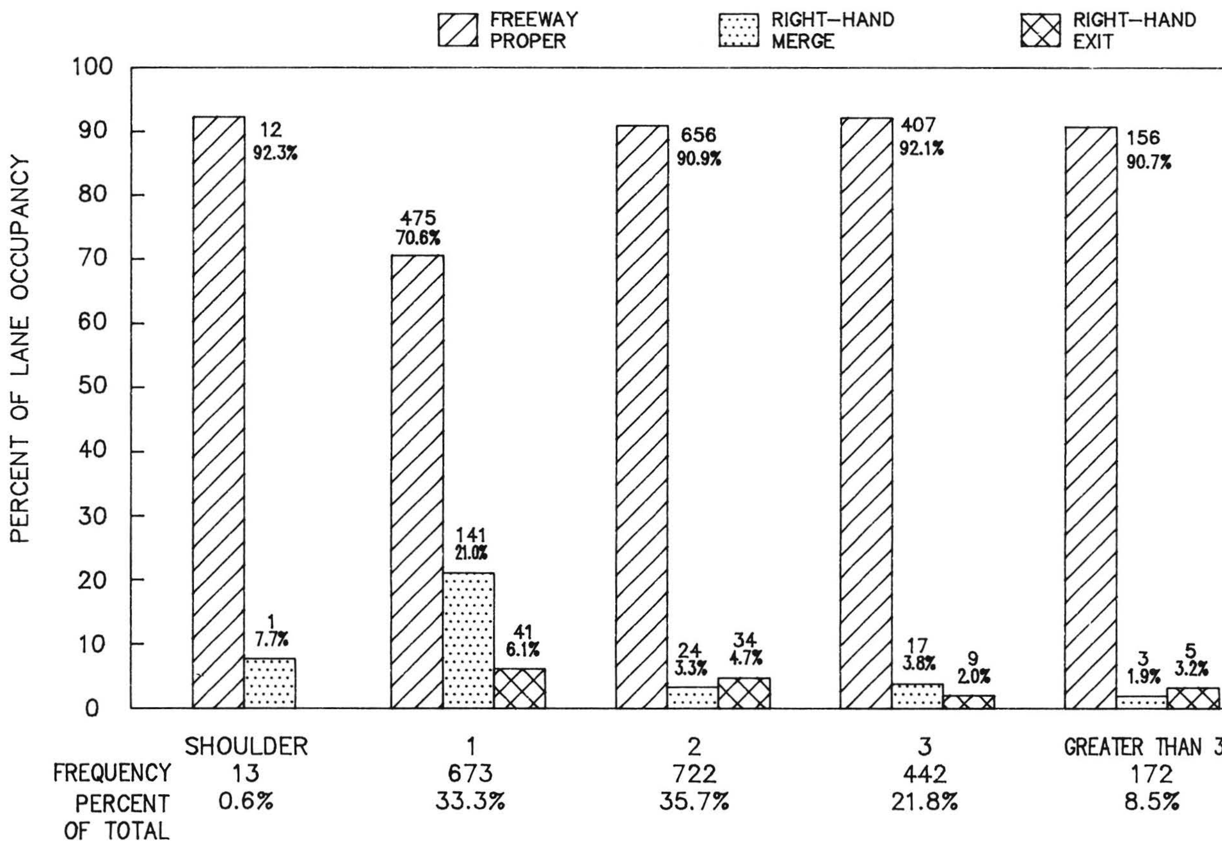


Figure 24. Freeway lane occupied by truck by accident area (lane count starts from right-hand road edge).

The distribution of truck driver action immediately prior to the accident is represented as figure 25. The majority of the accidents (54.8 percent) occurred when the truck was going straight and the second highest incidence of accidents occurred when the truck driver changed lanes (28.1 percent). Trucks were out of control immediately prior to the accident in 169 occurrences or 7.6 percent of the total accidents. The highest proportion of accidents, by truck/trailer combination type, involving a change of lane maneuver involved tractor/semitrailers and doubles.

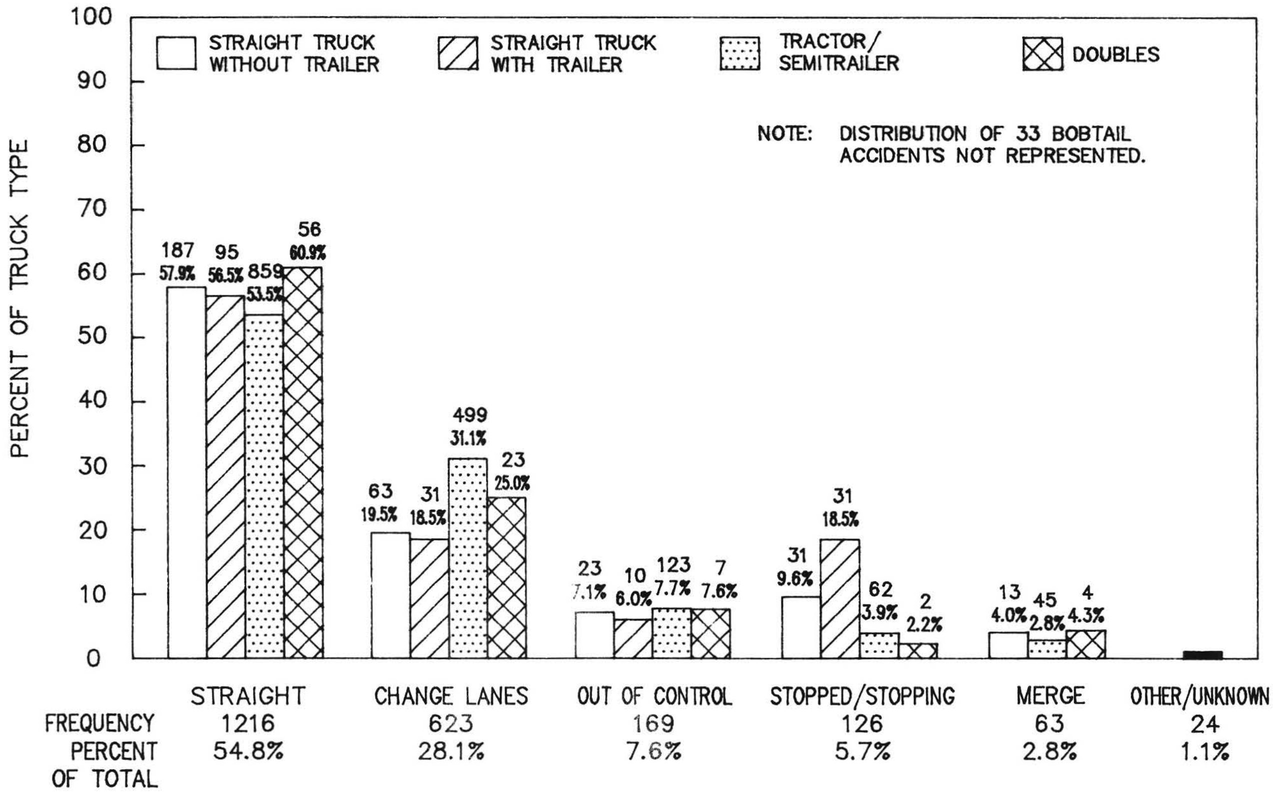


Figure 25. Primary truck driver action immediately prior to the accident by truck/trailer combination type and total truck accidents.

INFORMATION ON ADDITIONAL VEHICLES DIRECTLY INVOLVED IN TRUCK ACCIDENTS

The urban truck data file was structured to provide detailed information on the first vehicle that impacted or was impacted by the truck in addition to detailed information on the investigated truck/trailer combination. Information on any additional vehicles (i.e., for accidents involving 3 or more vehicles) involved in each accident was restricted to the total number of vehicles, vehicle type, and total killed and/or injured.

The type of vehicle that was first impacted by or impacting the truck is presented in figure 26. The vast majority of the first vehicles were passenger cars, vans, pickup trucks, and four-wheel utility vehices (92.6 percent). Straight trucks over 10,000 lb gross vehicle weight were the first vehicle in 49 cases (2.4 percent) and tractor/semitrailer combinations were the first vehicle in 69 cases (3.4 percent).

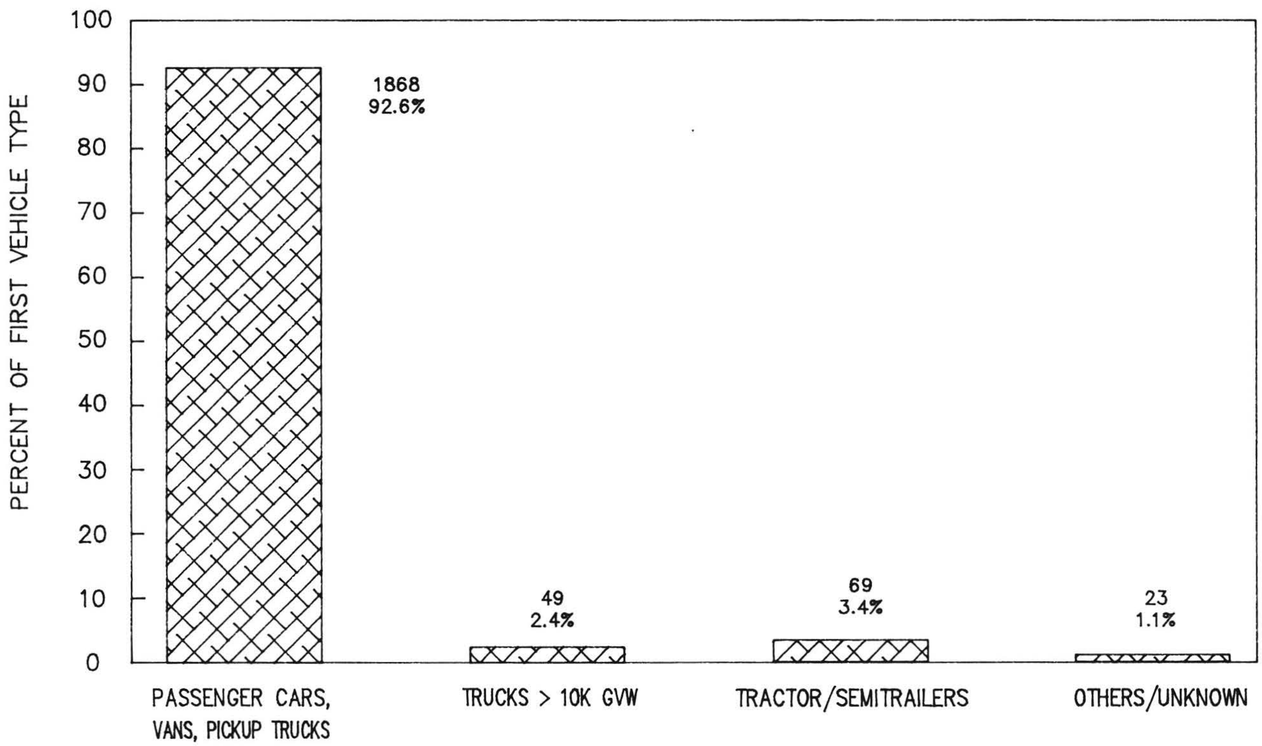


Figure 26. Type of first vehicle impacted by or impacting the truck.

Figure 27 presents the driver actions of the first vehicle impacted by or impacting the truck immediately prior to the accident. Proceeding straight on the freeway (54.5 percent), stopped (14.4 percent), and changing lanes (12.6 percent) were the three highest actions of the first vehicle driver prior to the investigated truck accident. In 160 accidents (7.9 percent) the first vehicles were trying to merge with the traffic stream.

The driver gender of the first vehicle impacted by or impacting the truck is represented by figure 28. Males were the drivers in the majority of cases accounting for 64.9 percent, females for 34.3 percent of those accidents where the gender was recorded.

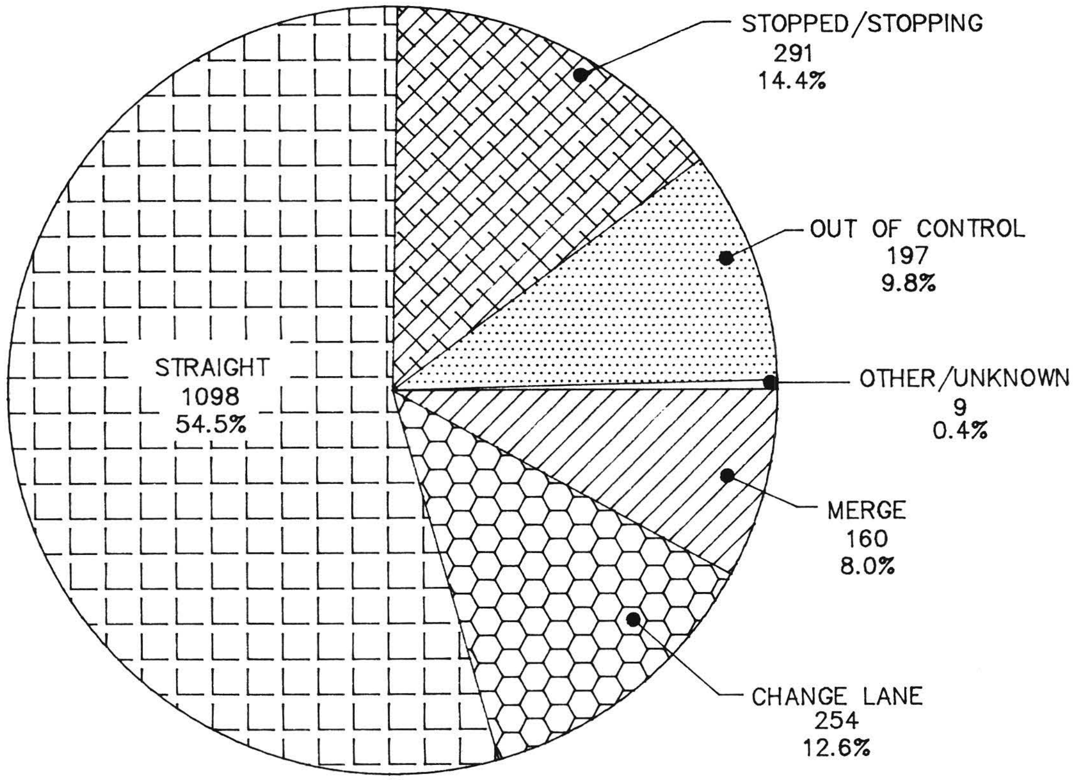


Figure 27. Driver actions of the first vehicle impacted by our impacting the truck immediately prior to the accident.

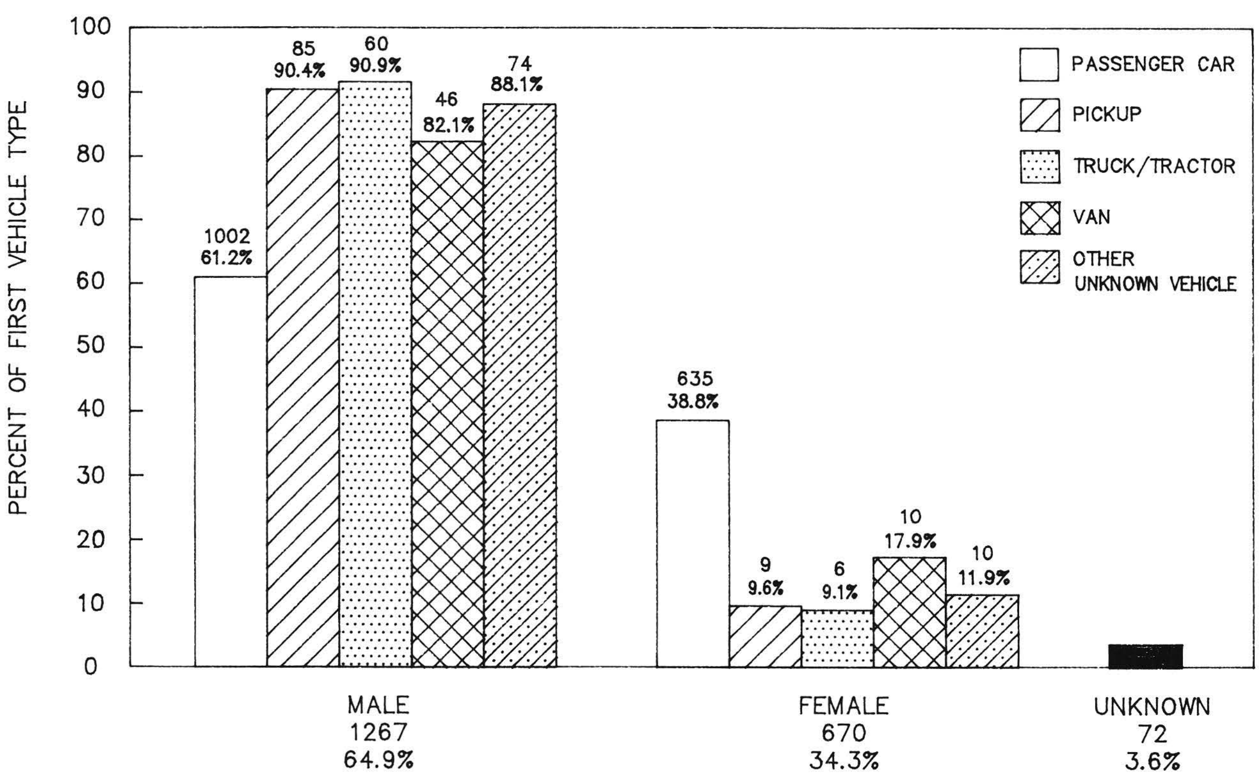


Figure 28. Driver gender of the first vehicle impacted by or impacting the truck.

Drivers of the first vehicle impacted by or impacting the truck were recorded as performing a hazardous action in 598 accidents. Figure 29 indicates that the most common type of hazardous action performed by the first vehicle was improper lane use (8.3 percent), following too close (7.9 percent), and speed too fast for conditions (6.7 percent).

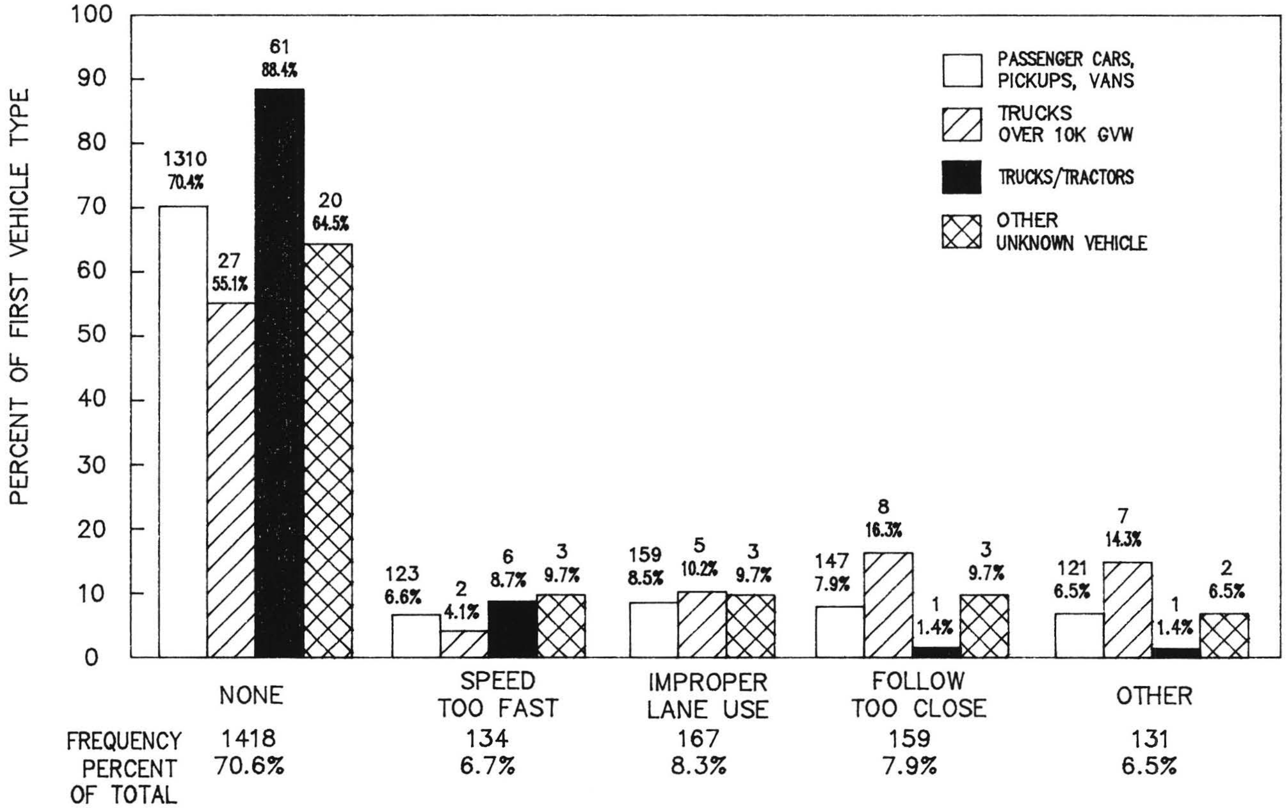


Figure 29. Type of hazardous action of driver of first vehicle impacted by or impacting the truck.

The age groups of the first vehicle driver, by vehicle type, is presented in figure 30. The largest age group represented is the 21 to 40 year old group. This age group accounted for 56.4 percent of the first vehicle drivers.

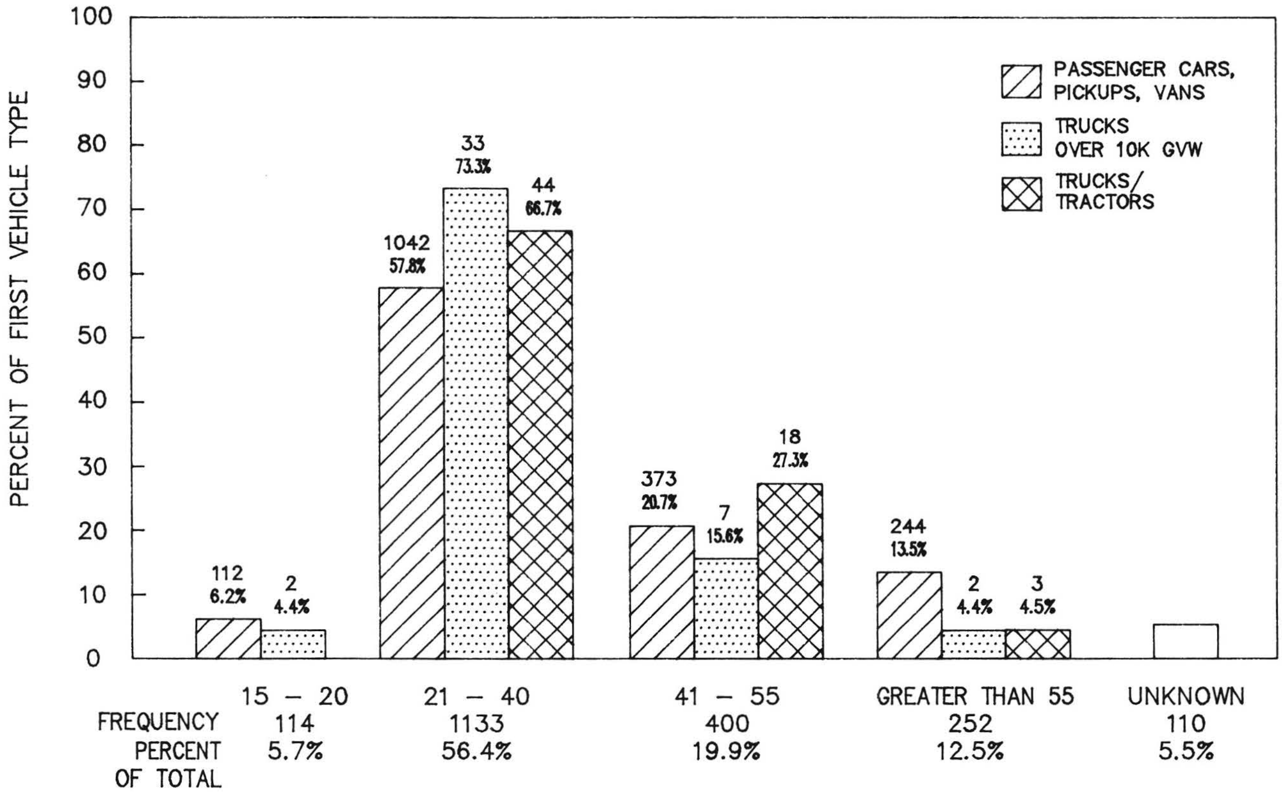


Figure 30. Driver age of first vehicle impacted by or impacting the truck by vehicle type.

TRUCK ACCIDENT SEVERITY

A summary of truck accident fatalities by vehicle of occupancy and the truck/trailer type involved in the accident is presented in figure 31. The largest number of fatalities were incurred with tractor/semitrailers in which three truck occupants and five occupants of other vehicles were killed. Accidents involving tractor/semitrailers accounted for 72.8 percent of the total fatalities. The largest number of persons killed in any individual truck accident was one.

Figure 32 presents a summary of the injuries by truck/trailer type involved and vehicle of occupancy. There were a total of 866 injuries resulting from the investigated accidents; 148 of which were occupants of the truck and 718 were occupants of the other involved vehicles. The largest percentage of injuries (57.6 percent) were experienced by occupants of other vehicles in collisions with tractor/semitrailers.

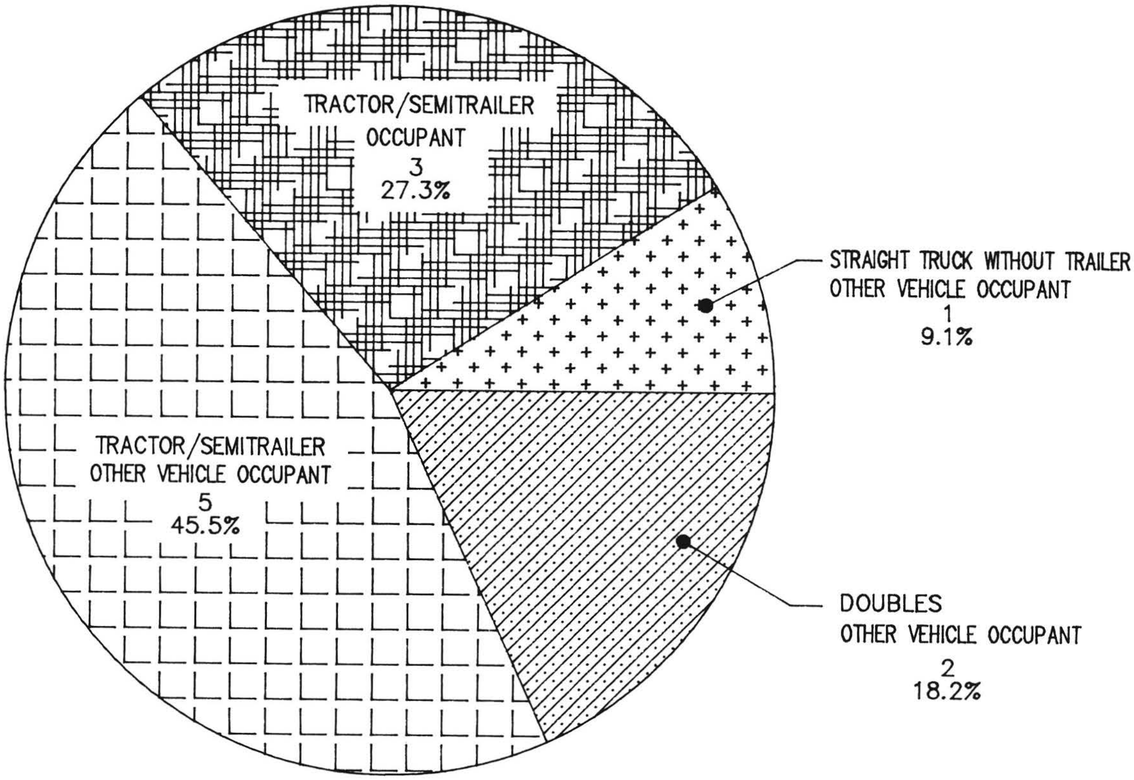


Figure 31. Truck accident fatalities by truck/trailer combination type and vehicle occupancy.

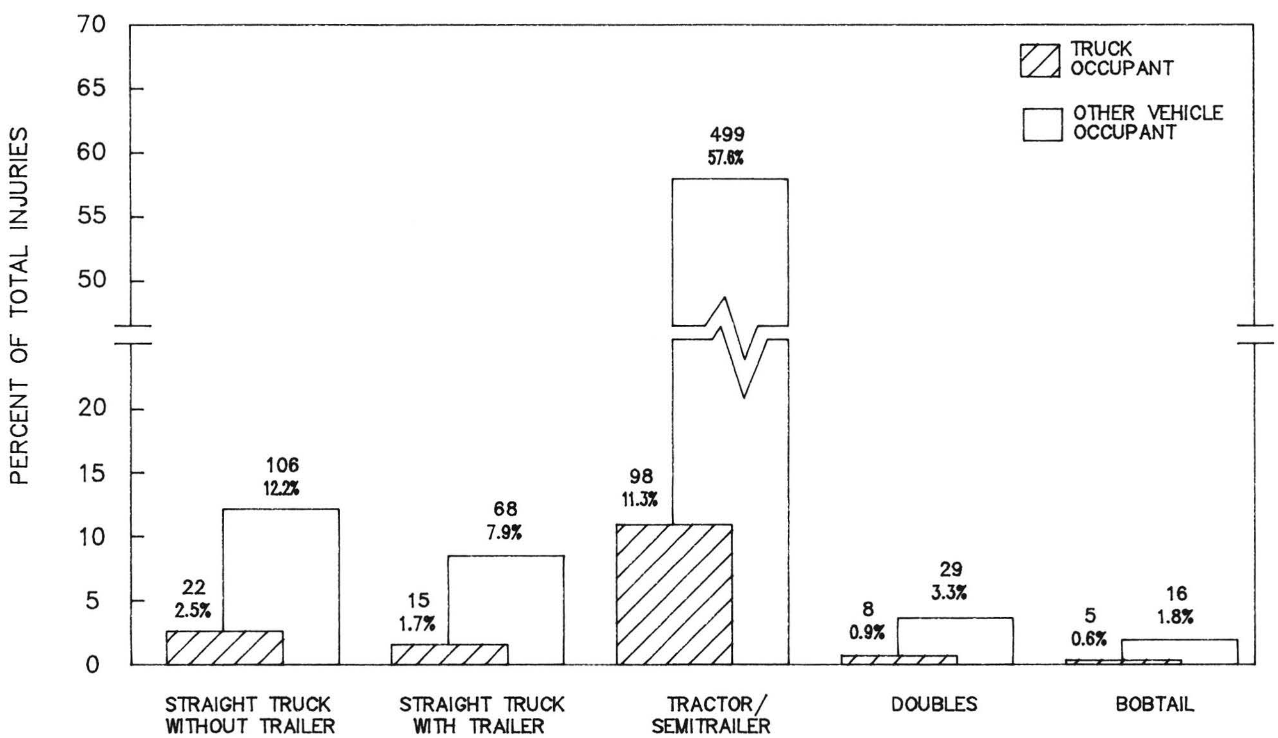


Figure 32. Truck accident injuries by truck/trailer combination type and vehicle of occupancy.

The average accident severity rates per 1,000 accidents are presented in table 4. Doubles had the highest fatality rate with an average of 21.7 fatalities per 1,000 accidents. Bobtails had the highest average injury severity rate of 636.4 persons injured per 1,000 accidents. The second highest average injury rate was exhibited by straight trucks with trailers at 494.0 injuries per 1,000 accidents.

Table 4. Average accident severity rates for combinations of truck/trailer types.

Truck/Trailer Type	Number of Accidents	Number of Fatalities	Average Fatalities per 1,000 Accidents	Number of Injuries	Average Injuries per 1,000 Accidents
Straight Truck Without Trailer	323	1	3.1	128	396.3
Straight Truck With Trailer	168	-	-	83	494.0
Tractor/Semitrailer	1,605	8	5.0	597	372.0
Doubles	92	2	21.7	37	402.2
Bobtail	33	-	-	21	636.4
Total	2,221	11	5.0	866	389.9

COMPARISON OF TRUCK AND PASSENGER VEHICLE ACCIDENTS

Computerized summaries of all accidents that were coded as occurring on the selected freeway segments from 1985 through September 1986 were obtained as part of this project. These summaries were investigated to identify accidents which were erroneously coded as occurring on the selected freeways. This was necessary since the computerized searches included accidents on surface streets that were in the vicinity of freeways. The determination of a magnitude of accident characteristics for the passenger vehicle population was determined by subtracting the appropriate characteristic of both the unverified and verified truck populations. Since only verified accidents were included in the truck population, this removed 125 truck type cases from the analysis. This was done because the verification process was designed to eliminate cases that could not be proven to involve trucks. Assuming that they were definitely part of the other vehicle population may have biased the analysis. A total of 17,962 freeway accidents, involving vehicles other than a truck, were identified for the 3.75-year analysis period. The comparisons between trucks and passenger vehicle types contained in this section of the report are based on the following categories:

- Passenger Vehicle: All of the freeway accidents that did not involve a truck were termed as passenger vehicle accidents. This category includes, therefore, all freeway accidents that occurred on the same freeway segments and during the same time period as the truck accidents that were analyzed minus the total truck accident population.

- Straight Trucks: All trucks over 10,000 lb gross vehicle weight that had the power and hauling portion of the truck attached together as a single unit are referred to as straight trucks. It is the sum of straight trucks with trailers and straight trucks without trailers used in the previous sections of this report.

- Tractor/Trailer Combination: Tractor/trailer combination is the sum of tractor/semitrailer and doubles, used in the previous section of this report.

- Total Truck: Total truck includes the sum of all the truck accidents (2,221) used in the previous section of this report. This total includes the 33 bobtail accidents that occurred over the 3.75-year analysis period.

Comparison of Accident Characteristics

A summary of the accidents by year is presented in figure 33. The distributions of the total annual accidents between the different vehicle types remain relatively constant from year to year. The number of accidents during 1988 is lower for all analysis categories since only 9 months of data were available. If the accident frequency of the first 9 months

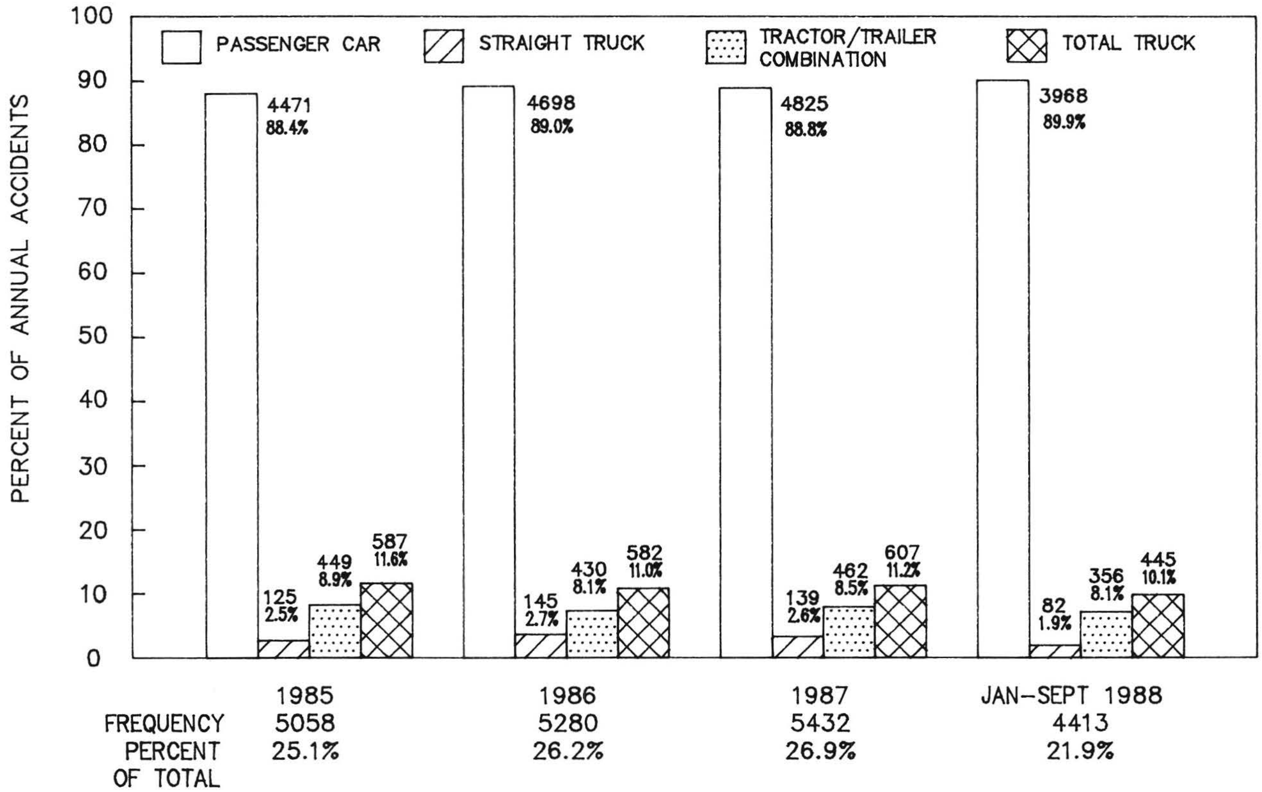
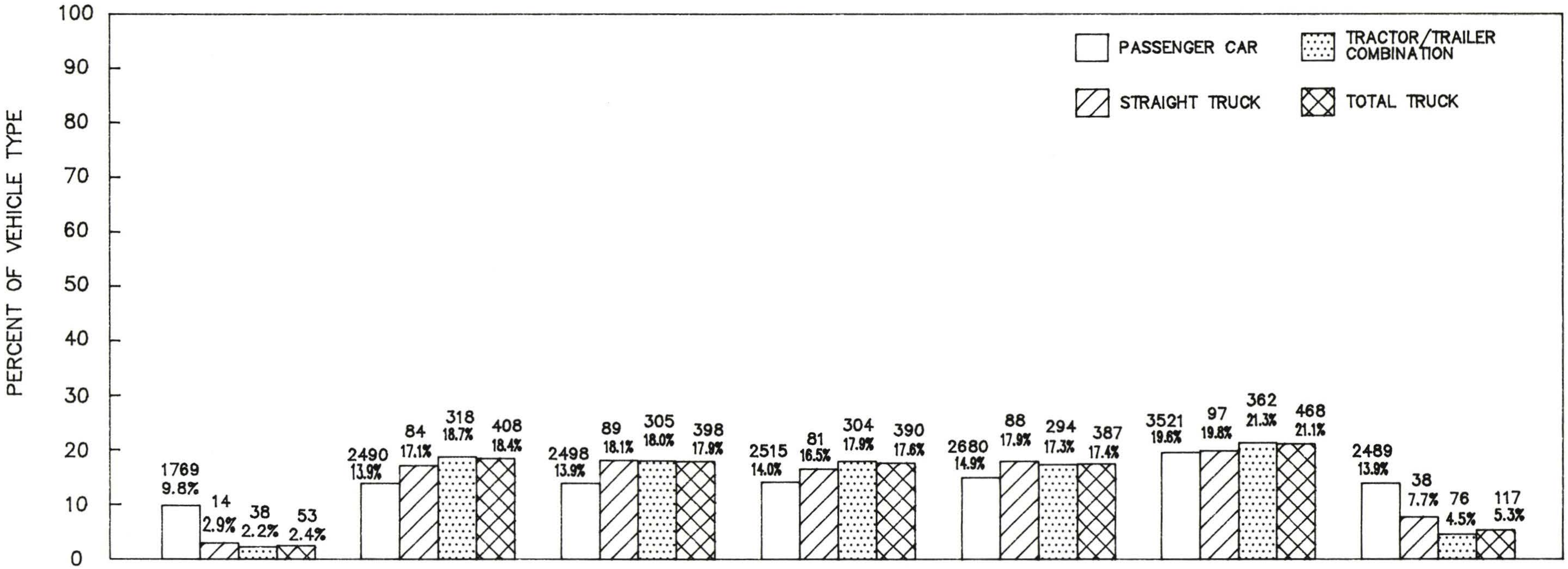


Figure 33. Distribution of all accidents by year of analysis.

of 1988 continues through December 31, 1988 then the 1988 passenger vehicle accidents will increase by 10 percent, tractor/trailer combination accidents will increase by 2.6 percent, and the straight truck and total truck accidents will decrease by 22 and 2 percent, respectively.

Figure 34 presents the day of week comparison between truck and passenger vehicle accidents. The highest percentage day for both truck and passenger vehicle accidents occurred on Friday, accounting for 21.1 and 19.6 percent, respectively. There is a difference between truck and passenger vehicle accidents on Saturdays and Sundays. Truck accidents are substantially below passenger vehicle accidents on these days; 2.4 percent of the truck accidents occurred on Sunday as opposed to 9.8 percent of the passenger vehicle accidents.

The distribution of all accidents by time of day is presented in figure 35. There was a higher percentage of passenger vehicle accidents than truck accidents from midnight until 6:00 a.m. and from 6:00 p.m.



	SUN	MON	TUE	WED	THU	FRI	SAT
FREQUENCY	1822	2898	2896	2905	3067	3989	2606
PERCENT OF TOTAL	9.0%	14.4%	14.3%	14.4%	15.2%	19.8%	12.9%

Figure 34. Distribution of all accidents by day of the week.

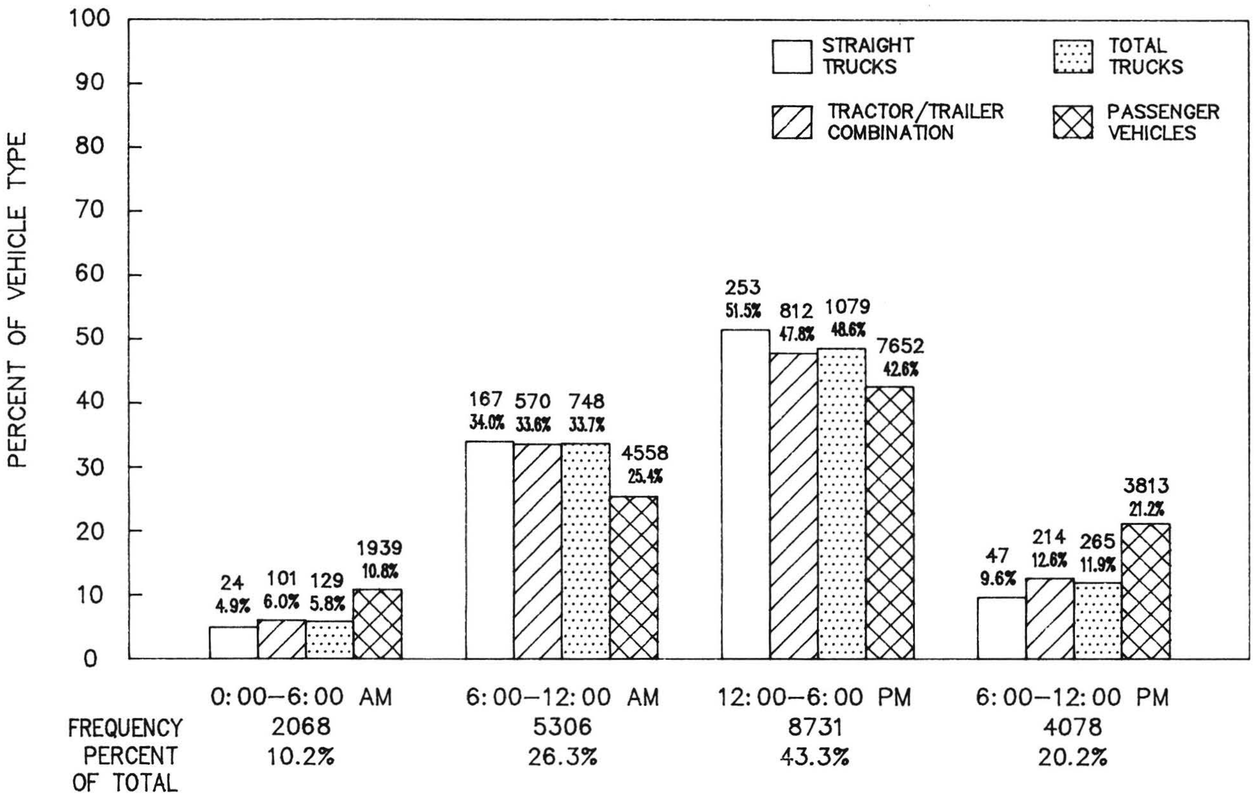
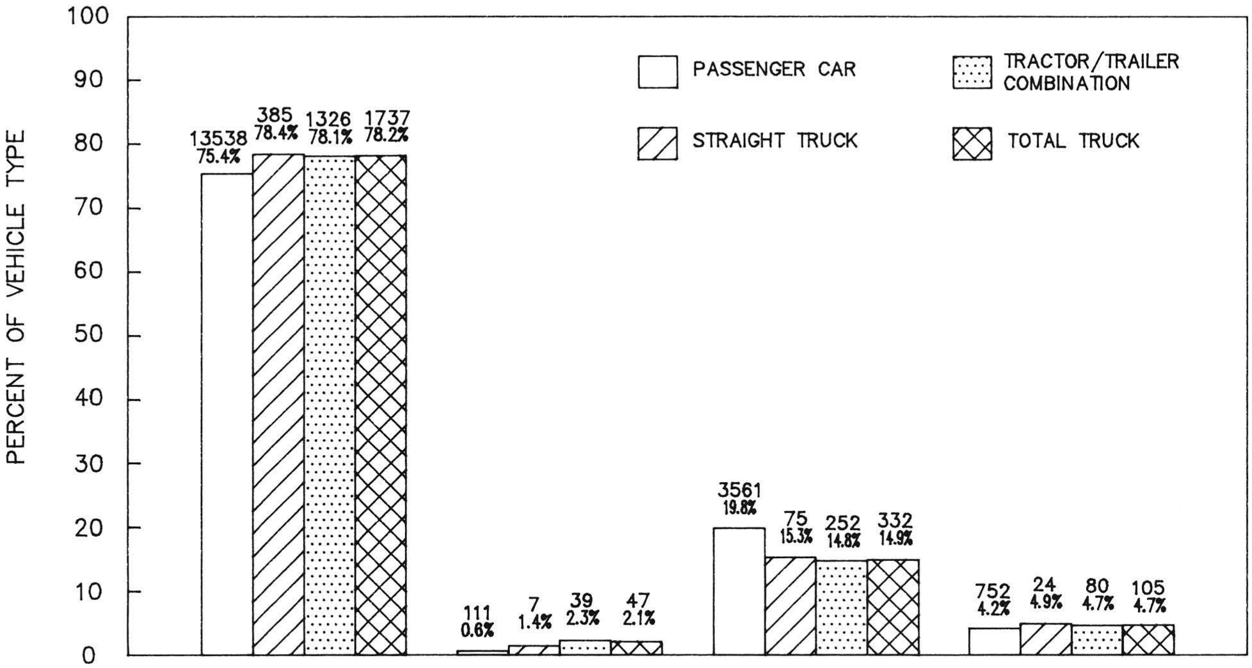


Figure 35. Distribution of all accidents by time of day.

until midnight. The percentage of truck accident occurrence is higher than that for passenger vehicle accidents during the remaining time periods. The highest percentage of truck accidents occurred from noon to 6:00 p.m. when straight trucks experience over 51 percent of their accidents.

A comparison of accidents by weather conditions is presented in figure 36. Trucks and passenger vehicles exhibit similar trends in accidents according to the weather conditions. As expected, the highest number of accidents, approximately 75 percent, occurred during clear/cloudy conditions and the lowest percentage during conditions of fog. The high and low percentage of accidents are more an indication of prevalent weather conditions than of accident propensity. Approximately 5 percent more accidents occurred during rainy weather with the passenger vehicles than with trucks.



	CLEAR OR CLOUDY	FOG	RAIN	SNOW
FREQUENCY	15275	158	3893	857
PERCENT OF TOTAL	75.7%	0.8%	19.3%	4.2%

Figure 36. Distribution of accidents by weather condition.

Figure 37 presents a comparison of accidents by road surface conditions. As expected, the percentages of figure 37 closely resemble the results of the weather condition comparisons. A larger percentage of passenger vehicles were involved with wet pavement accidents than were trucks. This difference was greater for the wet road surface, by percent, than the difference exhibited by rainy weather conditions of figure 36.

A comparison of trucks and passenger vehicles by the type of accident displays large differences, as presented in figure 38. The majority (64.6 percent) of the accidents involving passenger vehicles on the freeway were related to rear-end accidents, whereas rear-end accidents involving trucks only accounted for 28.5 percent of the truck accident experience. Sideswipe accidents accounted for 48.8 percent of all the truck accidents that occurred on the freeway but only occurred in 5.3 percent of the passenger vehicle accidents. A small percentage of truck accidents were classified as fixed-object accidents (5.3 percent); while fixed-object accidents accounted for 17.2 percent of the passenger vehicle freeway accident occurrence.

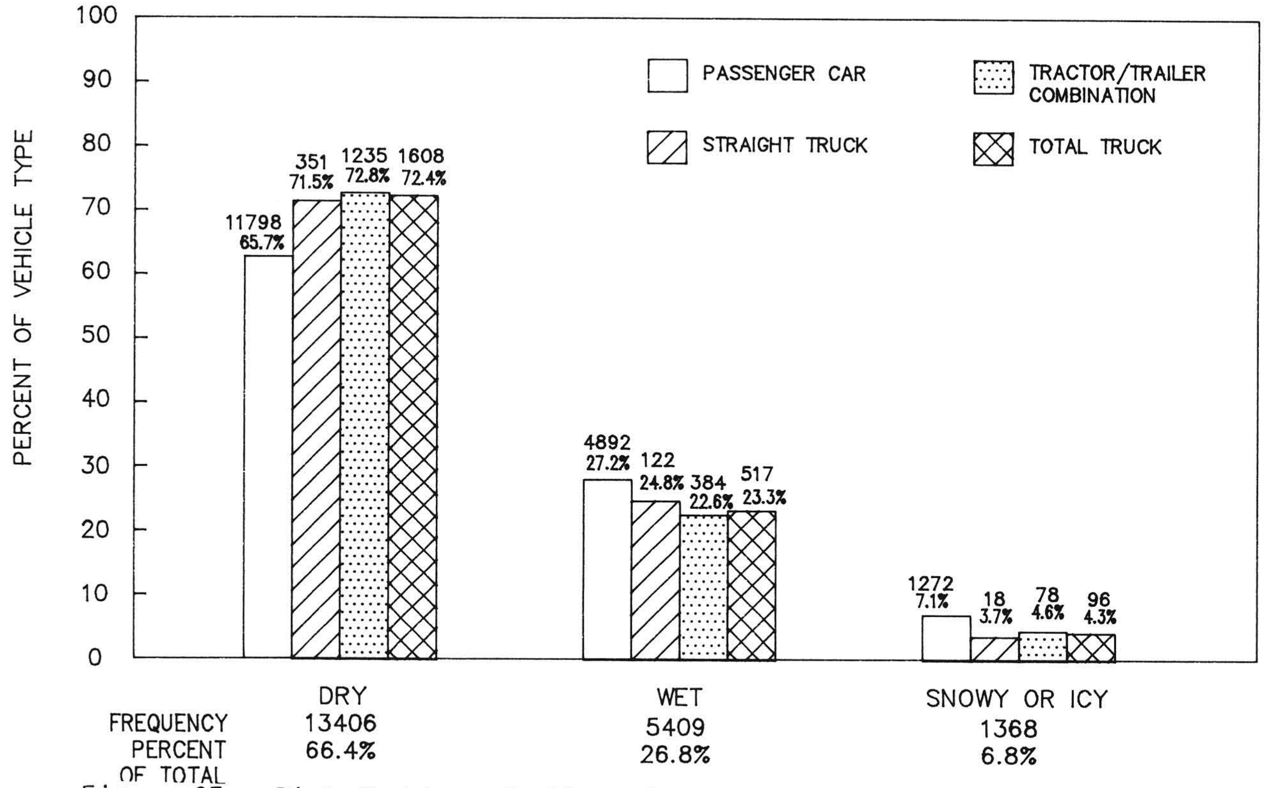


Figure 37. Distribution of all accidents by road surface condition.

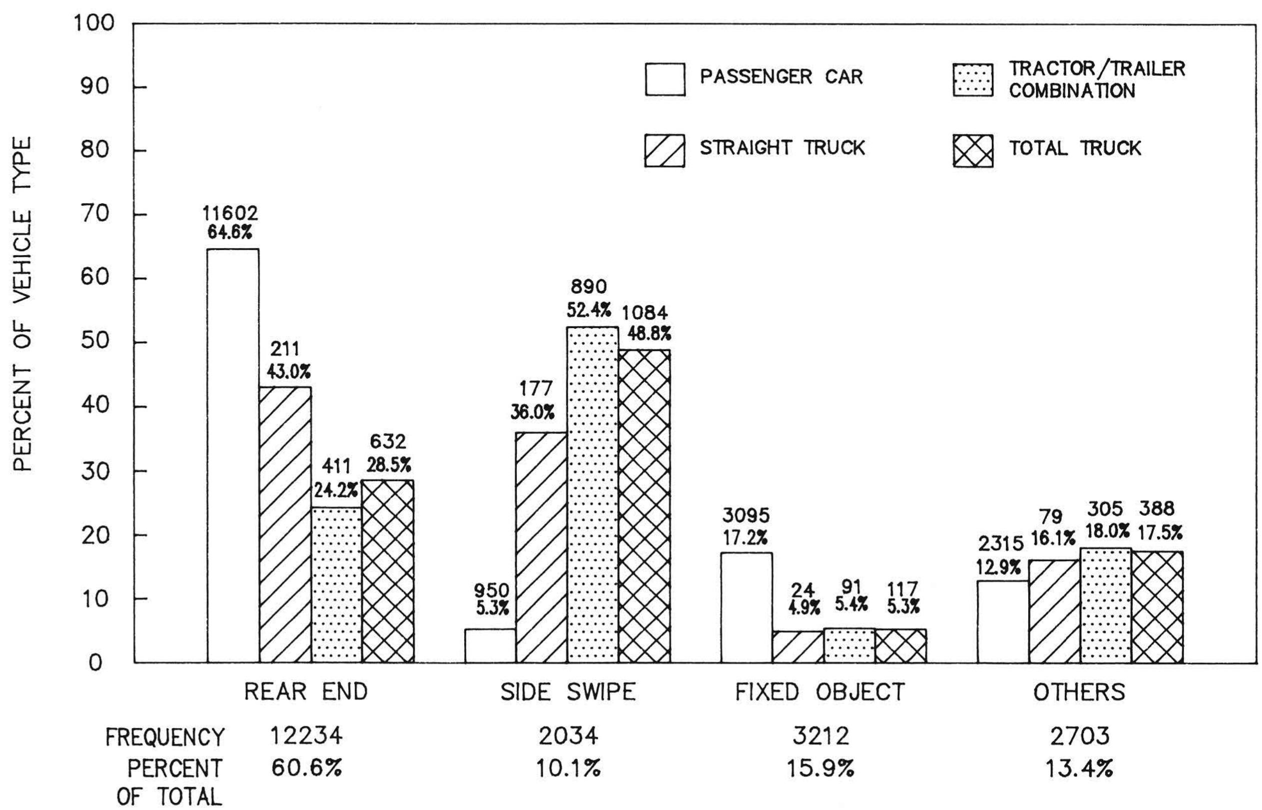


Figure 38. Comparison of type of accident by vehicle type for all accidents.

A comparison of the persons killed or injured per 1,000 accidents involving at least 1 truck and per 1,000 accidents involving passenger vehicles is presented in figure 39. A total of 11 persons were killed in the 2,221 accidents involving at least 1 truck. This results in an average of 5 persons killed for every 1,000 accidents which involved at least 1 truck. For the 17,962 accidents involving passenger vehicles 39 persons were killed for an average of 2.2 persons per every 1,000 accidents. Similarly, the 2,221 accidents involving at least 1 truck injured 866 persons; while the 17,962 accidents involving passenger vehicles resulted in a total of 9,643 persons being injured. The resultant rates are 389.9 persons injured per 1,000 accidents involving at least 1 truck and 536.9 persons per 1,000 accidents involving passenger vehicles. The injury rate for accidents that do not involve trucks is, therefore, higher than a comparable rate for accidents involving at least one truck. An injury occurs, on the average, in 53.7 percent and a fatality in 0.2 percent of the passenger vehicle accidents. The injury and fatality percentage for truck accidents were 39.0 and 0.5, respectively. Since the fatality rate is higher for truck involved accidents, however, the injuries sustained in accidents involving at least one truck are more severe.

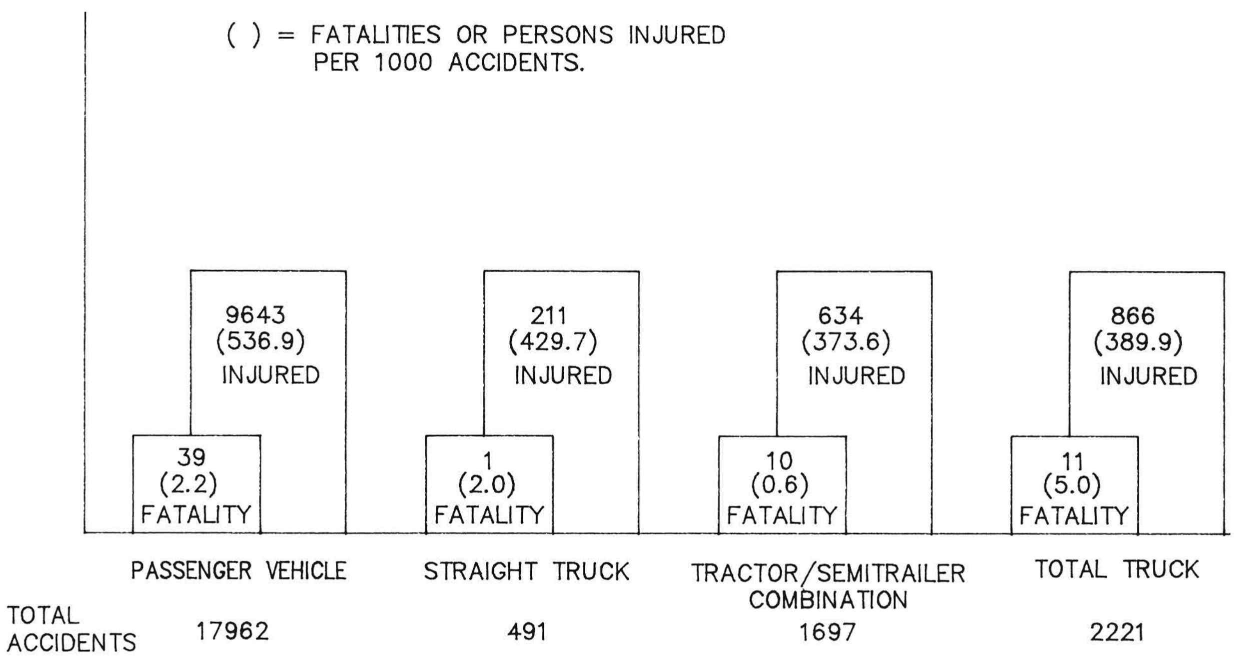


Figure 39. Comparisons by vehicle type of fatalities and persons injured per 1000 accidents.

CHAPTER 3 - COMPARATIVE ANALYSIS OF TRUCK ACCIDENT MAGNITUDE

Three different methods of determining accident magnitude were used for this project. Three different methods were used since the literature review did not reveal any prior studies which used a proven method for evaluating the magnitude of truck accidents on urban freeways. The majority of studies were either not appropriate for urban freeways or disclosed problems with regard to biases in the accident stratification by vehicle type, or by comparing truck accident experience based on only the proportion of truck mix to the total traffic stream. The three different analysis methods are influenced by and respond to each of the above problems in a different manner.

TRADITIONAL METHOD

The traditional method of determining accident magnitude requires dividing the accident frequency by a measure of exposure. The underlying assumption is that the opportunity for an accident is dependent only on the presence of a vehicle in the traffic stream. A section of roadway, therefore, that has twice the traffic volume can be expected to have twice as many accidents as a roadway segment with only half as much volume. Dividing the accident frequency by a measure of traffic volume essentially normalizes the accident occurrence, thereby, permitting comparisons between sites and among vehicle types. Associated advantages and disadvantages of the traditional method include that:

- The traditional method has been used by traffic safety analysts for many years. As a consequence the results are accepted by the majority of traffic engineering professionals.
- The accident rates resulting from applying the traditional methods can be compared to analysis results obtained from different studies (assuming sound experimental designs).
- Accidents are categorized by the type of vehicle involved in the accident. If the accident involved a passenger car and a truck it is categorized as a truck accident. Subsequent analysis of this accident will typically treat it as a truck accident using only truck exposure factors (such as truck million vehicle miles of travel) to normalize the data. This method accounts for the presence of trucks but it does not account for the presence of the passenger vehicle involved in the crash.

- ADT estimates are frequently obtained by deploying mechanical traffic volume counters for a 24-hour period. The resultant counts are used as the ADT usually with no temporal adjustment. The number of large trucks is typically estimated by performing short manual counts of the trucks passing a spot on the roadway. The truck counts in conjunction with the total volume is used to obtain the percent truck mix figure. The result is potentially large inaccuracies in both the total volume and truck mix estimates.

The traditional method of analysis was made as accurate as possible by breaking the analysis into levels of traffic density. The analysis of traffic characteristics reported in the previous chapter revealed that there were wide variations in accident experience by the time of day. This corresponds to associated variations in the time of day relationship with traffic volumes and percent truck mix. For example, from 12 midnight to 6:00 a.m. hourly traffic volumes would drop below 1,000 vehicles and the number of trucks present in that traffic stream would often result in percent truck mixes greater than 30 percent.

The accident data, both the urban truck and other vehicle data bases, were stratified by time of day, vehicle type and freeway segment. The ADT and percent vehicle mix, by vehicle class, were then assigned to each 6-hour period based on 24-hour total vehicle and truck counts. The exposure, by vehicle miles, from each analysis segment accrued within each 6-hour time of day were totaled to obtain an overall accident rate by time of day and the total truck accident rate.

The results of the time of day accident experience over all the analysis segments are presented in table 5. The data of table 5 are stratified by the type of vehicle and by whether the type of accident which occurred within the specified time frame were single or multiple-vehicle accidents.

Figure 40 presents the single-vehicle accident rate by time of day. The largest single-vehicle accident rate of 88.40 accidents per 100 million vehicle miles (100 MVM) occurred with passenger vehicles between the hours of 12 midnight and 6:00 a.m. Tractor/trailer combinations experienced a higher single-vehicle accident rate than straight trucks with the highest rate occurring between 12 noon and 6:00 p.m.

Table 5. Accident experience and exposure by vehicle type and time of day.

Vehicle Type	Time Period: 12 Midnight to 6 a.m.			6 a.m. to 12 Noon			12 Noon to 6 p.m.			6 p.m. to 12 Midnight			Total Exposure (100 Million Vehicle Miles)
	Multiple Vehicle Accidents	Exposure (100 Million Miles Traveled)	Number of Single-Vehicle Accidents	Multiple Vehicle Accidents	Exposure (100 Million Miles Traveled)	Number of Single-Vehicle Accidents	Multiple Vehicle Accidents	Exposure (100 Million Miles Traveled)	Number of Single-Vehicle Accidents	Multiple Vehicle Accidents	Exposure (100 Million Miles Traveled)	Number of Single-Vehicle Accidents	
Straight Truck	20	0.462	4	154	2.823	13	232	2.929	21	41	0.859	6	7.073
Semi Trucks	85	2.434	16	513	5.260	57	737	5.539	75	196	3.681	18	16.914
Total Trucks[1]	107	2.898	22	678	8.083	70	983	8.468	96	241	4.538	24	23.986
Passenger Vehicles	1,233	8.009	708	3,521	60.851	1,044	6,352	78.389	1,298	2,751	39.973	1,055	187.222

1 - Includes 33 bobtail accidents.

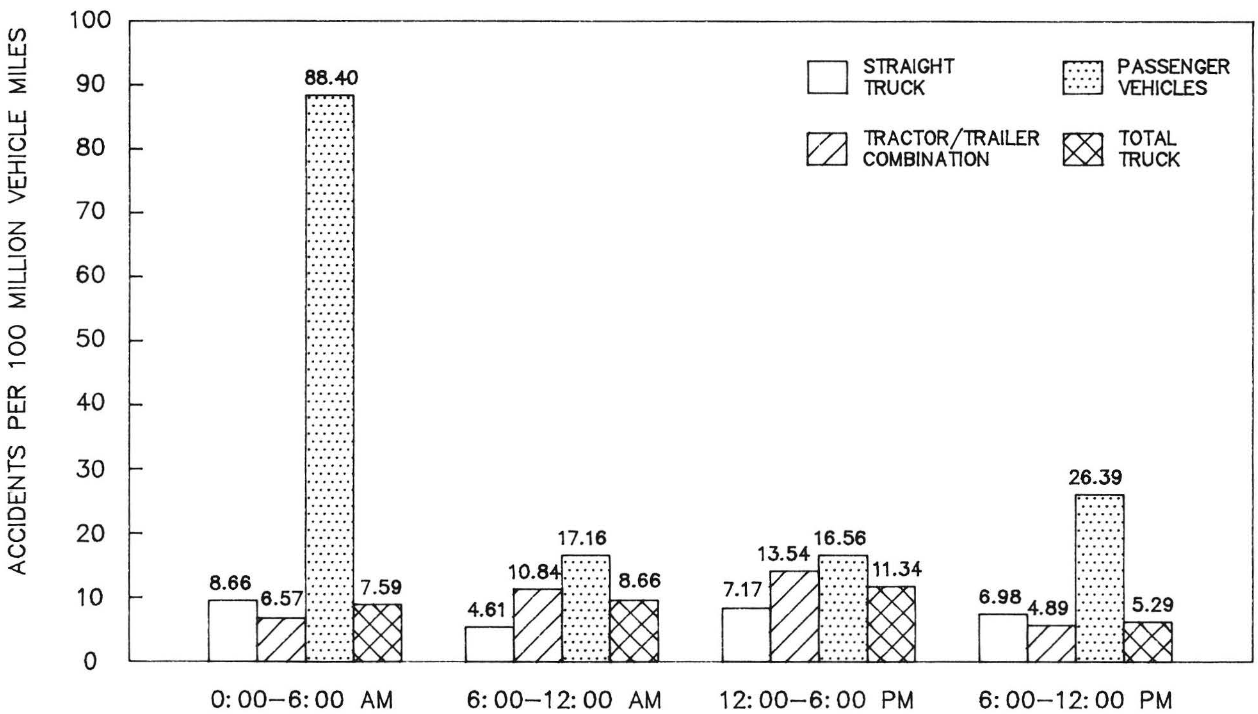


Figure 40. Single-vehicle accident rates (accidents per 100 million vehicle miles) by vehicle type and time of day.

The overall single-vehicle accident rate comparison between trucks and passenger vehicles is presented in figure 41. Truck/trailer combination vehicles had a higher overall single-vehicle accident rate (9.81 accidents per 100 MVM) than straight trucks. The single-vehicle rate of passenger vehicles is more than double (21.93 accidents per 100 MVM) the overall single-vehicle accident rate of any truck type.

The accident rates for accidents involving more than one vehicle are presented in figure 42. Passenger vehicles had a higher multiple-vehicle accident rate than total trucks during the hours of 12 midnight to 6:00 a.m. and from 6:00 p.m. to 12 midnight. The accident rates of both total trucks and semi trucks are greater than passenger vehicle rates between the hours of 6:00 a.m. to 6:00 p.m. Straight trucks had a lower accident rate than the passenger vehicle rate for all time periods.

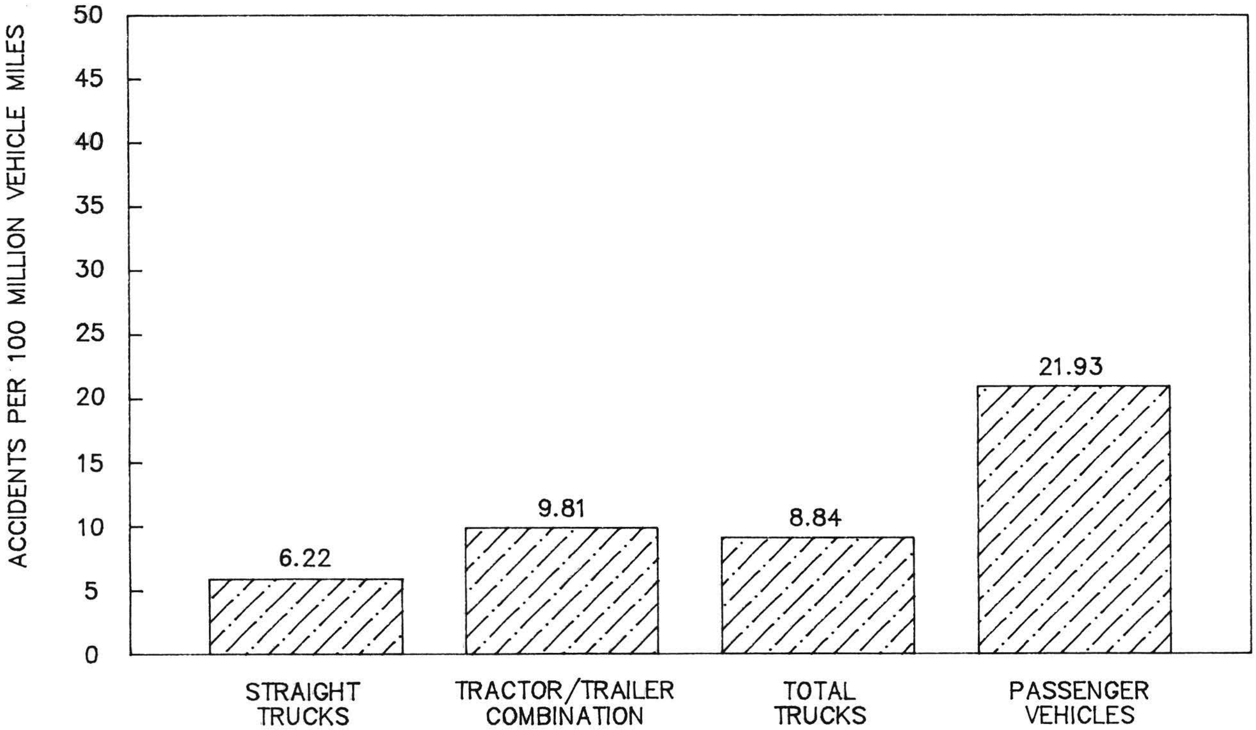


Figure 41. Overall single-vehicle accident rate comparison between trucks and passenger vehicles (accidents per 100 million vehicle miles).

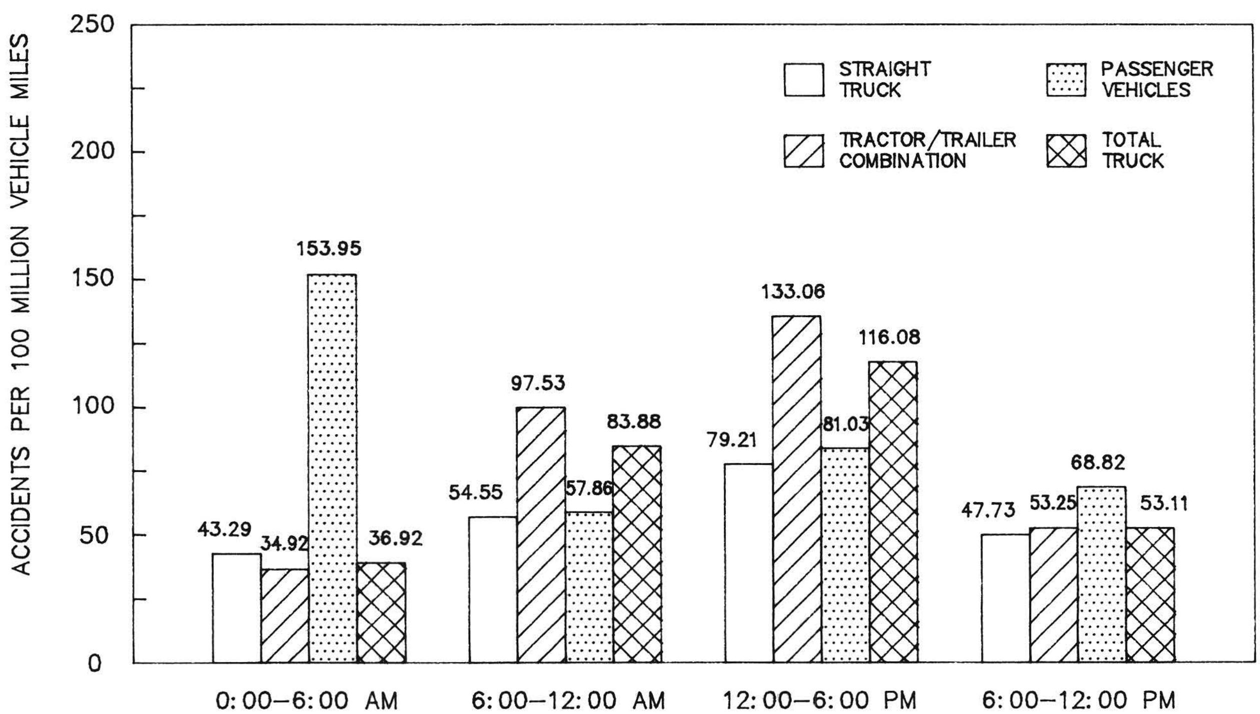


Figure 42. Multiple-vehicle accident rates (accidents per 100 million vehicle miles) by vehicle type and time of day.

The overall multiple-vehicle accident rate comparison between trucks and passenger vehicles is presented as figure 43. Tractor/trailer combinations display the highest overall multiple-vehicle accident rate of 90.52 accidents per 100 MVM. The overall multiple-vehicle accident rate for total trucks is greater (83.76 accident per 100 MVM) than that exhibited by passenger vehicles (74.01 accidents per 100 MVM).

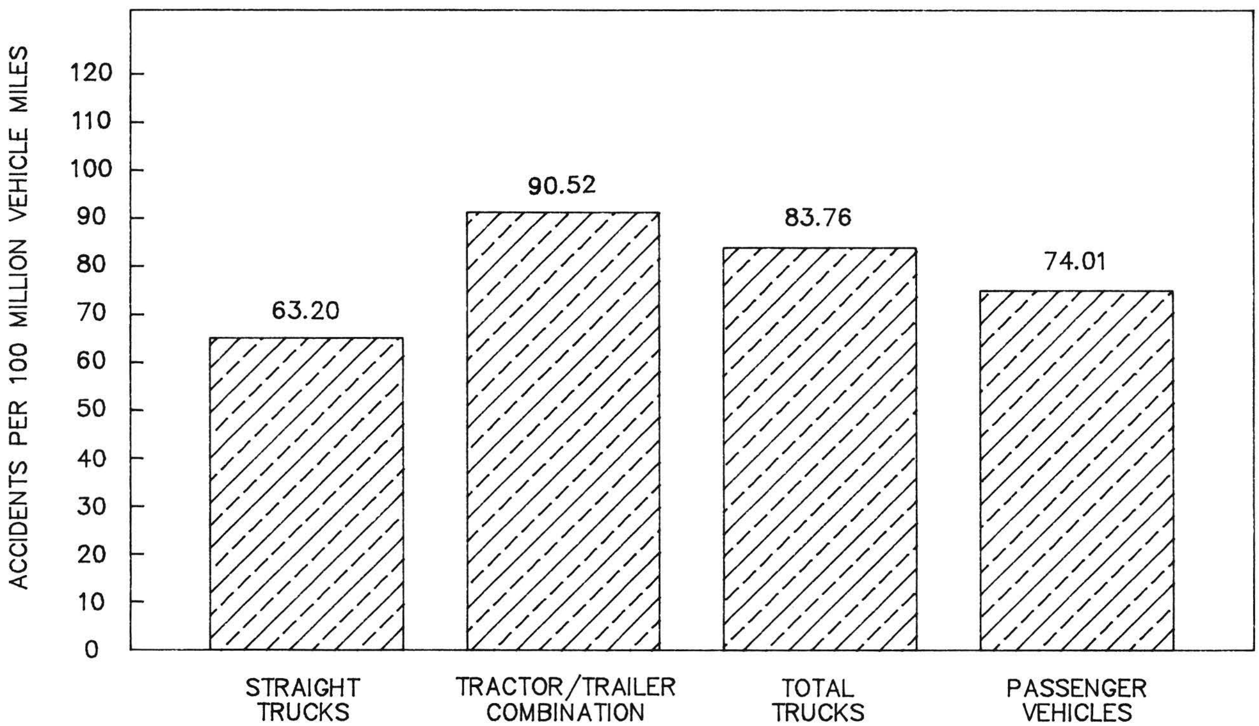


Figure 43. Overall multiple-vehicle accident rate comparison between trucks and passenger vehicles (accidents per 100 million vehicle miles).

The accident rates of single-vehicle and multiple-vehicle accidents combined are presented in figure 44. Semi trucks had a higher rate than any other vehicle type. The overall total rate for passenger vehicles exceeded the total rate but only by 0.33 accidents per 10 million vehicle miles traveled.

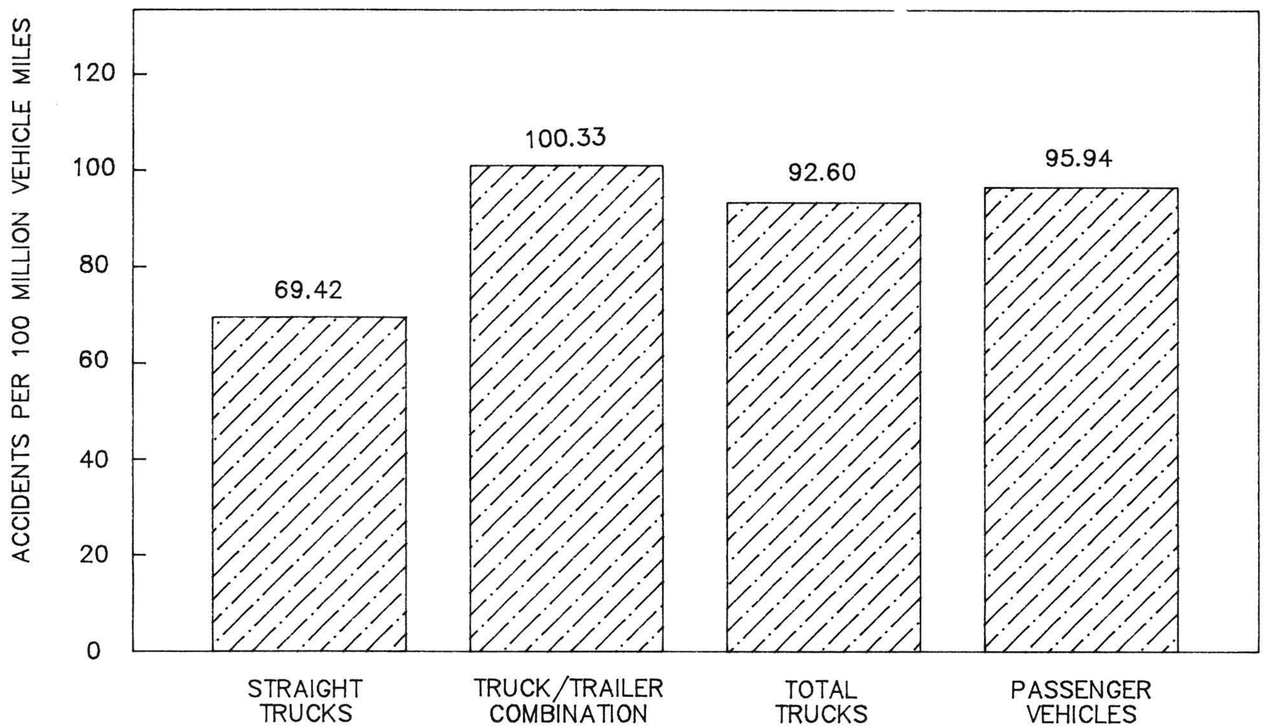


Figure 44. Overall total accident rate comparison between trucks and passenger vehicles (accidents per 100 million vehicle miles).

ADJUSTED TRADITIONAL METHOD

Accidents can occur between any combinations of vehicles on a roadway in addition to single-vehicle accidents with the facility features themselves. If the vehicle population is assumed to exist of only trucks and passenger vehicles then multiple-vehicle accidents can occur as passenger vehicle-passenger vehicle, passenger vehicle-truck, and truck-truck accidents. The traditional method considers passenger vehicle-truck as well as truck-truck accidents as appropriate numerators in the determination of truck accident rates; while simultaneously only using a truck exposure measure in the denominator. Applying this same concept to the determination of passenger vehicle accident rates results in a higher rate than customarily achieved by the traditional rate. The adjusted traditional method for determining accident rate (R) by summing accidents (A) between passenger vehicles (P) and trucks (T) with exposure (M) over the various vehicle class pairs is:

$$R_P = \frac{A_{PP} + A_{PT}}{M_P} \quad (1)$$

$$R_T = \frac{A_{TT} + A_{PT}}{M_T} \quad (2)$$

The result is that accidents between passenger vehicles and trucks are used twice (i.e., in the numerator of both the passenger vehicle and truck rate formulas). Since the traditional method uses passenger vehicle-truck accidents in the determination of the truck accident rate it should also be used in the determination of the passenger vehicle accident rate for multiple-vehicle accidents. This is appropriate since accidents between passenger vehicles and trucks are not mutually exclusive and vehicles must be present for the accident to occur.

The numbers of multiple-vehicle accidents and exposure used for the adjusted traditional method are presented in table 6. The 1,891 accidents involving trucks and passenger vehicles were included in the multiple-vehicle accident rate determination of both the passenger vehicle and truck accident rates. The results of the accident rate determination are presented as figure 45.

Table 6. Determination of the multiple-vehicle accident rate by the adjusted traditional method.

Vehicle Type	Number of Accidents With		Total Multiple-vehicle Accidents	Total Exposure (100 million vehicle miles)	Accident Rate (100 million vehicle miles)
	Passenger Vehicles	Trucks			
Total Trucks	1,891	118	2,009	23.986	83.76
Passenger Vehicles	13,857	1,891	15,748	187.222	84.11

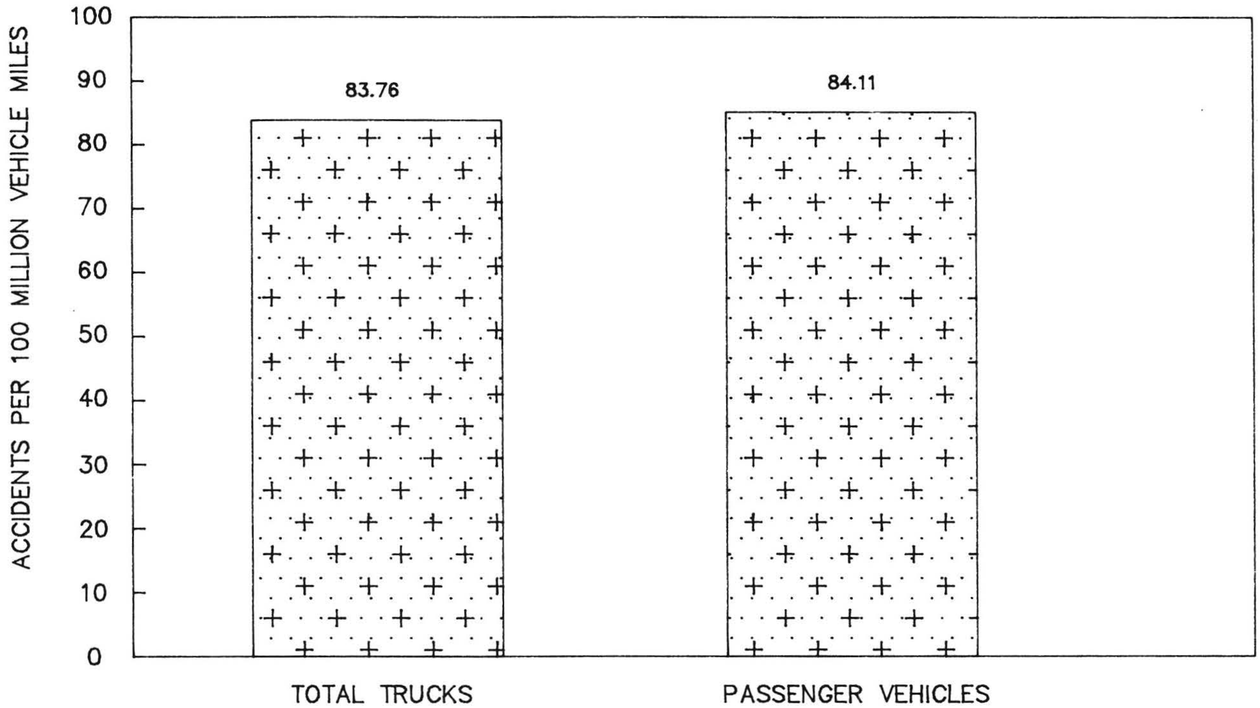


Figure 45. Overall multiple-vehicle accident rate comparison between total trucks and passenger vehicles by the adjusted traditional method (accidents per 100 million vehicle miles).

QUASI-INDUCED EXPOSURE METHOD

The problems associated with obtaining accurate exposure data have resulted in a proposed method of determining exposure by using information routinely available from most accident reporting systems. The induced exposure method is based on the assumption that the relative exposure for certain classes of drivers, vehicle types, driving environment, etc. is proportional to the number of times that the analysis category is an innocent victim in collision accidents. Associated advantages and disadvantages of the induced exposure method include:

- The method provides a quick and economical method of determining the population at risk.
- Method accuracy is not dependent upon traffic volume counts or estimates of percent truck mix.

- The induced exposure method was initially based on the responsible/nonresponsible determinations obtained from the investigations of single-vehicle accidents. This method was subsequently determined to contain inaccurate assumptions and provide questionable results. Recent applications have centered on assigning responsible/nonresponsible determinations based on the designation of the accident report using only two-vehicle accidents. Preliminary indications are that this approach eliminates the inaccuracies of the initial, single-vehicle induced exposure concept.

- The induced exposure method may provide different rates than those normally achieved by the use of traditional methods. There may be some reluctance by the professional community to accept the results due to their departure from the norm.

- It is not known if practices or prejudices of the reporting police officers influence the exposure estimates. If it is a factor there is a possibility that the bias will be more pronounced when investigating truck and passenger vehicle accidents.

The induced exposure method operates under the premise that the chance of an individual being an innocent victim in an accident is in direct proportion to their presence on the roadway. This inherently assumes that at fault drivers impact other vehicles in a random manner. If only multiple accidents where responsibility can be assigned are analyzed, then the above assumption can be extended to assuming that the innocent victim characteristics comprise a random sample of driver-vehicle combinations on the roadway. Since it is assumed to be a random sample the induced exposure method uses the information derived from the innocent victim characteristics to estimate exposure information. This has the advantage of not requiring potentially inaccurate vehicle counts or percent truck estimates to obtain measures of accident exposure.

The urban truck data file was constructed with information on hazardous actions that were attributed to the driver of trucks and of the first impacted vehicle. To obtain the required information for using the induced exposure method the urban truck data base was stratified by the number of vehicles involved in each accident. The 212 single-vehicle accidents were then eliminated from further consideration; leaving 2,009 multiple-vehicle truck accidents in the data base. The remaining cases were then searched to eliminate: (1) those accidents where no hazardous action was cited for either the truck or first impacted vehicles and (2) those instances where both the truck and first vehicle were cited for hazardous actions. The resultant data base of 1,341 accidents was then stratified by vehicle type to determine the responsible and innocent occurrences by vehicle types involved in the urban truck data base. There were 1,341 multiple-vehicle accidents where a hazardous action was assigned to either the truck or the first impacted vehicle; but not both. The urban truck data base, therefore, permitted the assignment of responsibility/innocent drivers in 66.8 percent (1,341/2,009) of the multiple-vehicle accidents.

There were 17,962 accidents not involving trucks that occurred on the same freeway segments and time period used for the urban truck file. Single-vehicle accidents accounted for 4,105 (table 5) of these accidents with the remaining 13,857 being multiple-vehicle accidents. Assuming that responsibility could be assigned in these accidents in the same percentage as found in the urban truck file (i.e., 66.8 percent) resulted in 9,250 passenger vehicle-passenger vehicle accidents of assignable responsibility. This was considered permissible because no analysis of vehicle driver characteristics within the other vehicle population was being performed.

The induced exposure matrix of table 7 indicates that there were a total of 183 accidents involving straight trucks where the responsibility for the accident could be attributable to the straight truck driver. Similarly, there were 125 accidents involving straight trucks where the straight truck was an innocent victim. Straight trucks were the responsible vehicle in 168 accidents with vehicles other than a truck.

The induced exposure method assumes that the marginal distribution of innocent victims is a random sample of the vehicles present on the roadway. The involvement of vehicle types as an innocent victim in an accident is, therefore, assumed to be a direct measure of their exposure. Thus, if overall system averages could be obtained, 94.9 percent of all the vehicles on the roadway, over all time periods including weekends and holidays, would be passenger vehicles. Similarly, tractor/trailer

Table 7. Quasi-induced exposure matrix for accident combinations involving different vehicle types.

	Responsible				
	Vehicle Type	Straight Truck	Semi Truck	Passenger Vehicle	Vehicle Totals
Innocent	Straight Truck	9	6	168	183 (1.7)
	Semi Truck	9	40	633	682 (6.4)
	Passenger Vehicle	107	369	9,250	9,726 (91.8)
	Vehicle Totals	125 (1.2)	415 (3.9)	10,051 (94.9)	10,591 (100.0)

( ) = percent

combinations and straight trucks comprise 3.9 and 1.2, respectively, of the total traffic stream. Comparing the distribution of responsible to innocent vehicle types provides an estimate of the involvement ratio. Straight trucks, for example, experienced 125 accidents as an innocent victim and were the responsible vehicle in 183 accidents. The involvement ratio for straight trucks is, therefore, 1.464 (183/125 = 1.464). This indicates that straight trucks are disproportionately overinvolved in accidents as the most responsible vehicle type. The induced exposure matrix for total trucks, presented in table 8, indicates the same results as those obtained from analyzing the different truck types separately. The total truck population is over represented as the responsible vehicle in those accidents involving a truck (i.e., involvement ratio of 865/540 = 1.602).

The involvement ratios of the different vehicle types and total trucks are presented in figure 46. Both straight and semi trucks exhibit an over involvement in responsible vehicle accidents by the induced exposure method. Passenger vehicles exhibit an involvement ratio of 1 which indicates the proportion of responsible accidents which could be expected from their induced exposure estimate.

Table 8. Quasi-induced exposure matrix for total trucks and total passenger vehicles.

	Responsible			
	Vehicle Type	Total Trucks	Total Passenger Vehicles	Vehicle Totals
Innocent	Total Trucks	64	801	865 (8.2)
Innocent	Total Passenger Vehicles	476	9,250	9,726 (91.8)
	Vehicle Totals	540 (5.1)	10,051 (94.9)	10,591 (100.0)

( ) = percent.

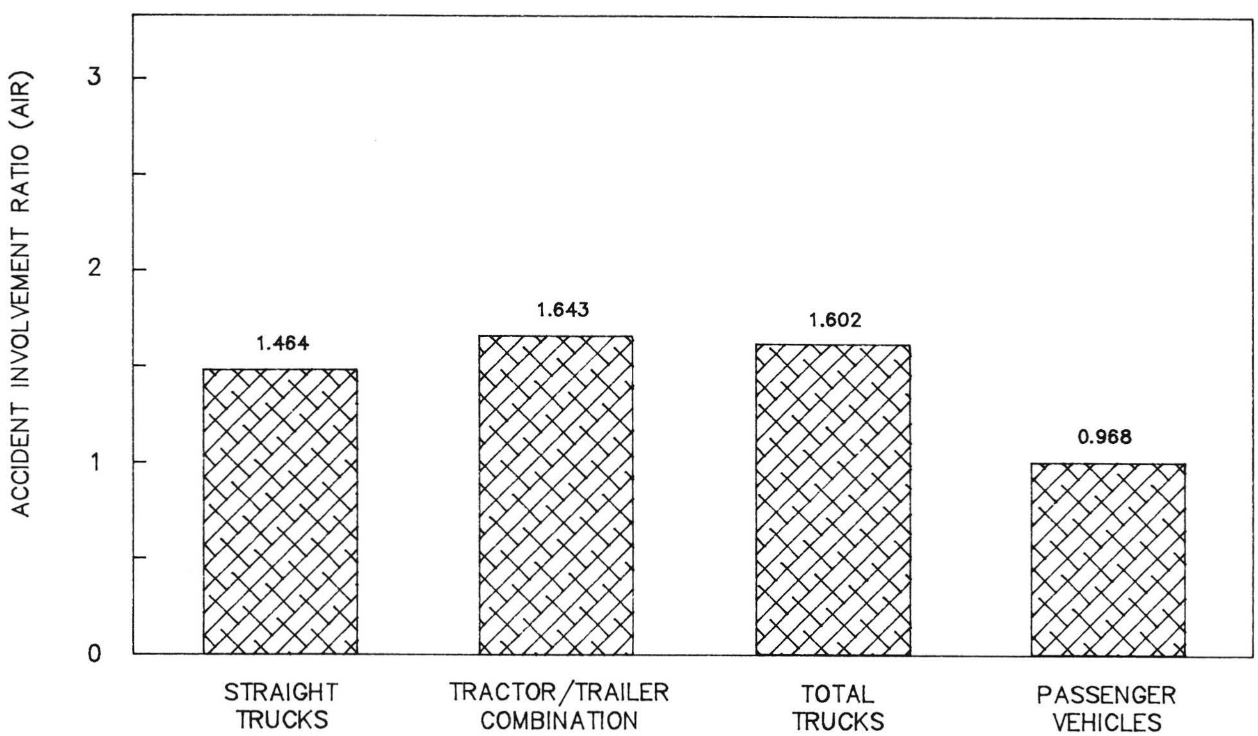


Figure 46. Accident involvement ratios of different vehicle types resulting from the induced exposure method.

SUMMARY OF TRUCK ACCIDENT MAGNITUDE RESULTS

A summary of the results from the traditional and adjusted traditional accident magnitude methods is presented as figure 47. The accident rate for trucks remains the same for both methods. When the accidents between passenger vehicles and trucks are included in the calculation of the passenger vehicle rate there is an increase over the traditional rate calculation. This increase is 10.10 accidents per MVM and is sufficiently large to result in a passenger vehicle accident rate which is larger than the total truck rate.

The quasi-induced exposure method indicates that trucks are overinvolved in multiple-vehicle accidents (involvement ratio of 1.602) while passenger vehicles are underinvolved (involvement ratio of 0.968). Since the analysis population for this study was separated into only the two categories of passenger vehicles or trucks an overinvolvement by one vehicle type will result in an underinvolvement in the remaining category. The inherent assumption with the induced exposure method is that the ratio of innocent victim to total accidents for a certain vehicle type is proportional to the exposure of that vehicle type on the roadway. Table 7 indicated, by this assumption, that tractor/semitrailer, straight trucks, and passenger vehicles comprised 3.9, 1.2, and 94.9, respectively, of the overall traffic stream. This proportional traffic mix may be true when the overall traffic composition, including weekends and holidays, is considered. The truck mix estimate from the quasi-induced assumption does, however, appear to be low. Two different conditions can, therefore, exist with regard to the quasi-induced method: (1) the truck mix estimates are lower than what actually exists and the quasi-induced involvement ratios are not accurate, or (2) the impact of weekends and holidays on truck volume is not properly taken into consideration with the result that volume based exposure methods are under estimating truck accident rates.

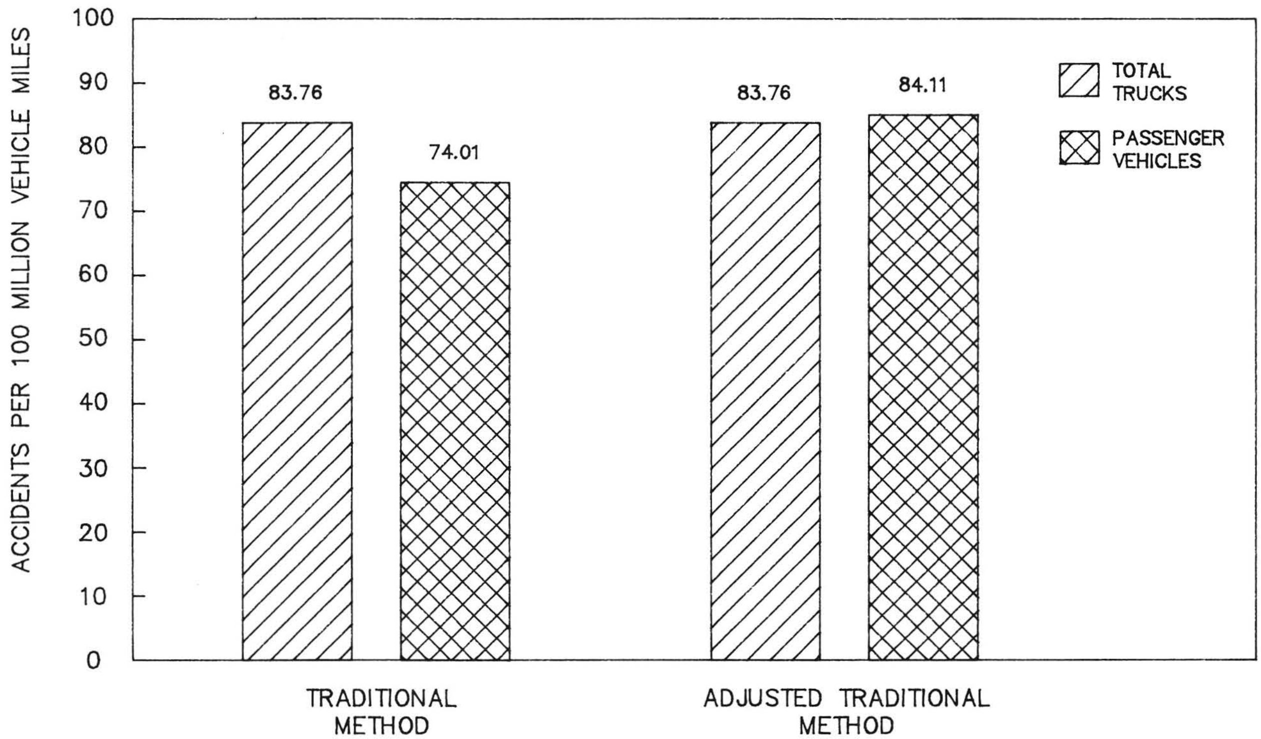


Figure 47. Comparison of traditional and adjusted traditional methods of determining multiple-vehicle accident rates.

CHAPTER 4 - OPERATIONAL CONSEQUENCES OF LARGE TRUCK ACCIDENTS

The disruption to normal traffic operations resulting from a truck accident is similar to disruption caused by other incidents with some major differences. One difference is that truck accidents have a greater potential for blocking a large portion of the freeway, and in some instances, totally blocking all lanes. In addition, truck accidents can result in very long lane closures due to lost cargoes or shifted loads.

While the potential impacts of truck accidents on freeway operations can be substantial, the resultant delay can be quantified by the time required for detection, response and clearance. Until the incident is completely cleared from the freeway, the flow past the incident is less than the demand flow due to the lane blockage. The total vehicle hours of delay is dependent upon the type of blockage, traffic management techniques used, and natural traffic diversion resulting from avoidance of an evident traffic backup. Computer models have been developed to assist in estimating the freeway delay resulting from traffic accidents. The computerized model developed for the Federal Highway Administration was used to estimate the freeway delay resulting from truck accidents.[31]

DATA SOURCES AND COLLECTION TECHNIQUES

Information on a total of 436 truck accidents was requested from the surveillance components of the traffic departments with jurisdiction over the freeway used in the accident analysis. The desired information on each incident included:

- Demand flow at the time of the accident.
- Initial bottleneck flow rate and associated time.
- Stabilized bottleneck flow rate.
- Time of lane(s) or entire freeway closure

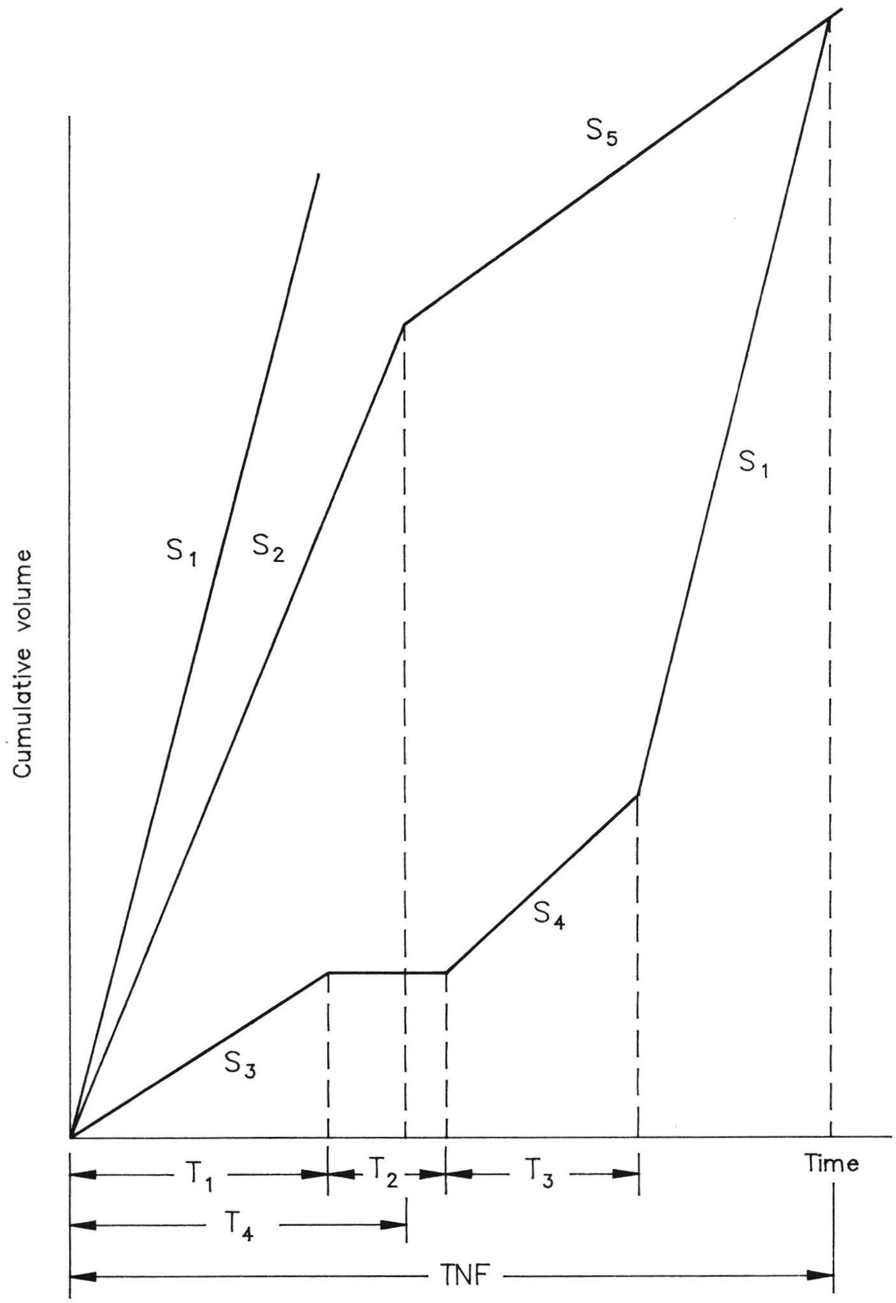
The log books, traffic volume records, and surveillance tapes of the agencies were searched to provide the required information. Acceptable traffic volume data and record of length of time that blockage occurred were identified for only 23 of the accidents. For 18 of the sample of 23 accidents, 5-minute volumes and mean speeds were available from a monitoring station near the accident site. However, for five accidents the only available volume information was in the form of hourly summaries from a count station near the accident site. These hourly summaries were supplemented by information from the accident report itself to provide adequate input data for the delay model.

The delay model used in this project assumes the theoretical form presented as figure 48. Assumptions necessary to achieve an acceptable estimate of delay included that:

1. Traffic was not diverted onto surface streets or other freeways due to the accident.
2. Express and priority lanes performed in a manner identical to regular lanes in the event of an accident.
3. The effect of "rubbernecking" was negligible.
4. The characteristics of the freeway at every point upstream of the accident site were constant and identical to the characteristics at the accident site.
5. Demands and bottleneck flow rates on the freeway were constant over significant stretches of time.

Assumptions 1 and 2 tend to lead to higher delay estimates while assumption 3 tends to lower the delay estimate. The net effect from all the above assumptions, therefore, is a relatively reliable estimate of freeway delay due to freeway accidents. The output of the model is delay, in vehicle-hours, experienced due to the demand of the freeway being greater than the "temporary" capacity. This provides lower estimates for delay than traditional methods of delay measure since the computer model provides delay for normal freeway conditions and delay resulting from the accident.

Figure 49 displays how the model inputs were constructed from volume data for a typical accident. For most accidents, the major assumptions made in the constructing model inputs were that: (1) demand during the



S_1 = Capacity flow rate of the freeway, veh./hr.
S_2 = Initial demand flow rate, veh./hr.
S_3 = Initial bottleneck flow rate, veh./hr.
S_4 = Adjusted bottleneck flow rate, veh./hr.
S_5 = Revised demand flow rate, veh./hr.
T_1 = Incident duration until first change, min.
T_2 = Duration of total closure, min.
T_3 = Incident duration under adjusted flow, min.
T_4 = Elapsed time under initial demand, min.
TNF = Total elapsed time until normal flow resumed, min.

Figure 48. Freeway delay model theoretical form.[2]

Five-minute time period begins at	Volume	
730	646	
735	647	Mean = Initial Demand, S2 Time Under Initial Demand, T4 = (T1 + T3)/2 = 17.5 min.
740	677	
745	640	
750	504	Accident occurs at 750, according to police report Initial Bottleneck Flow, S3
755	280	
800	334	
805	354	Mean = Adjusted Bottleneck Flow, S4 Time Under Adjusted Bottleneck Flow, T3 = 30 min.
810	333	
815	303	
820	347	
825	500	Normal conditions, according to police report, at 825
830	513	
835	562	Mean = Revised Demand, S5
840	561	

[From other data] Capacity Flow Rate, S1 = 2,000 vehicles per hour per lane x 5 lanes = 10,000 vehicles per hour

Duration of Total Closure, T2 = 0

Model Output: Total Delay, vehicle-hours = 949.10

Figure 49. Construction of freeway delay model inputs from 5-minute volume data.

first half of the accident (i.e., the accident and corresponding congestion) was equivalent to demand just prior to the accident, (2) demand during the second half of the accident was equivalent to demand just after the congestion was cleared, and (3) volumes recorded during an accident were equivalent to bottleneck flow rates. Break points, such as when the accident happened when revised bottleneck flow rates began, etc., were obtained for each sampled accident.

RESULTS OF OPERATIONAL CONSEQUENCES

Motorists passing six of the sampled accidents experienced no delay, as detailed by the model, (i.e., the temporary capacity of the freeway never dropped below the demand). Delay data, along with the model inputs used, are given for 17 sampled accidents on table 9. Of special note on table 9 is the wide distribution of the delay variable - especially the long "tail" containing two accidents with relatively large delay values. These two outlying "tail" accidents also were excluded from analysis using the freeway delay model for this project, primarily because major assumptions such as no diversion of traffic, constant upstream freeway characteristics, and other assumptions do not hold for such major incidents.

The model predicted an average delay of 914 vehicle-hours for approximately 13.2 minutes of delay per affected vehicle. In general, the accident sample is highly skewed to the low amounts of delay, with a few accidents causing most of the very substantial delay experienced in the total sample. These results compare favorably with those reported in reference.[42] The author reported an average delay of 779 vehicle-hours for each police-reported truck-involved incident including spills, stalls, fires, etc. on Los Angeles area freeways based on use of a delay model which did not include major incidents. He found an average delay due to accidents of 1,179 vehicle-hours or about 17.4 minutes of delay per affected vehicle. These averages differ slightly from the mean delay estimated for this project. The distribution described for the Los Angeles data also approximates project results.

Table 9. Accident sample model inputs and delay results.

S1	S2	S3	S4	S5	T1	T2	T3	T4	Total Delay, veh.-hrs.
6,000	3,939	3,764	3,764	3,939	15	0	0	15	6
8,000	2,832	1,650	1,650	2,832	10	0	0	10	20
10,000	5,152	5,299	5,299	6,972	25	0	0	12.5	43
10,000	6,339	4,874	4,874	6,339	25	0	0	25	178
8,000	6,447	5,627	6,498	5,406	50	0	20	35	333
8,000	4,734	3,625	4,204	3,477	45	0	15	30	392
8,000	5,484	2,768	2,768	4,248	30	0	0	15	448
8,000	4,038	2,664	2,664	3,408	60	0	0	30	730
6,000	4,857	1,743	1,743	4,560	25	0	0	12.5	794
6,000	3,905	2,734	2,734	3,905	60	0	0	60	913
10,000	7,830	6,048	3,902	6,530	5	0	30	17.5	949
6,000	5,349	3,979	3,979	4,989	85	0	0	42.5	2,690
8,000	5,262	1,756	3,786	4,353	45	0	30	55	3,722
8,000	2,175	95	522	1,052	60	0	60	60	3,875
6,000	3,855	869	869	2,508	90	0	0	30	4,090
8,000	4,421	2,536	2,536	2,892	150	0	0	170	8,475
8,000	6,256	2,670	1,238	3,593	20	10	145	85	29,753

S_1 = Capacity flow rate of the freeway, veh./hr.
S_2 = Initial demand flow rate, veh./hr.
S_3 = Initial bottleneck flow rate, veh./hr.
S_4 = Adjusted bottleneck flow rate, veh./hr.
S_5 = Revised demand flow rate, veh./hr.
T_1 = Incident duration until first change, min.
T_2 = Duration of total closure, min.
T_3 = Incident duration under adjusted flow, min.
T_4 = Elapsed time under initial demand, min.

Table 10 presents other interesting results for the modelled accidents. The five accidents which caused the most delay all had at least one unique characteristic which contributed to the problem. The accident with the highest delay involved a jackknifed truck and occurred during the height of the p.m. peak period, while the accident with the second-highest delay also involved a jackknifed truck and occurred prior to the a.m. peak period. The third through fifth-highest ranked accidents in terms of delay involved a cargo spill, a fuel spill with an overturned truck, and a fuel spill, respectively. There were not sufficient data, however, to construct an explanatory model based on accident details such as those contained on table 10.

Table 10. Details of 23 Seattle-area truck-involved accidents.

Estimated Delay (veh.-hrs.)	Cargo Spill	Fuel Spill	No. Vehs. Involved	Hour of Accident	Other Notes
0	No	Yes	1	500	Overturn
0	No	No	3	800	
0	No	No	2	800	
0	No	No	3	800	
0	No	No	3	1500	
0	No	No	2	1400	
6	No	No	3	1500	
20	No	No	1	900	
43	No	Yes	1	1500	
178	No	No	2	1500	
333	No	No	3	700	
392	No	No	4	600	
448	No	No	2	1800	
730	No	No	5	1400	
794	No	No	2	900	Jackknife
913	No	No	3	1400	
949	No	No	3	700	
2,690	No	No	2	600	
3,722	No	Yes	3	1500	
3,875	No	Yes	1	1900	Overturn
4,090	Yes	No	3	1000	
8,480	No	No	2	600	Jackknife
29,800	No	No	1	1700	Jackknife

Table 11 presents summary statistics for the modelled accidents (excluding the two major incidents) for two other measures of effectiveness output by the freeway delay model. The two measures shown, time to normal flow and maximum length of queue are both highly correlated with delay by the nature of the freeway delay model used. Nonetheless, table 9 illustrates that truck accidents on urban freeways have large impacts on normal freeway operations. Even the accident which represents the mean in terms of severe delay in the accident sample, without the major incidents, causes abnormal flow for 56 minutes and results in a 1.4 mile queue.

Table 11. Summary statistics for Seattle-area accident sample excluding major incidents.

Statistic	Time to Normal Flow, Minutes	Maximum Length of Queue, Miles
Low	0	0
High	185	5.9
Mean	56	1.4
Median	47	0.7
Mode	0	0
Standard Deviation	55	1.6

CHAPTER 5 - ECONOMIC CONSEQUENCES OF TRUCK ACCIDENTS

The costs associated with truck accidents consist of the same components as those associated with other vehicle accidents. They include accident-related costs (vehicle repairs, medical expenses and economic losses associated with fatalities), increased vehicle operating costs due to additional delay, clean-up costs and the cost of motorist time lost to additional delay. The costs associated with truck accidents are, however, in many cases higher than with other vehicle accidents. The economic analysis of urban freeway truck accidents was estimated by considering four major cost components: (1) accidents, (2) delays, (3) vehicle operation, and (4) clean-up.

ACCIDENT COSTS

Accident costs for trucks can vary widely depending not only on the vehicle damage but also on the potential for freeway facility damage and on the type and degree of cargo loss. While average costs of accidents are available from a number of sources including the National Safety Council (NSC), the National Highway Traffic Safety Administration (NHTSA), and the Federal Highway Administration (FHWA), there are few studies which assign costs to truck accidents. A study conducted by Rollins and McFarland is one source that provides direct costs for urban truck accidents although it is based on data which is dated.[43] The study determined that urban truck property damage only (PDO) accidents have a 20 percent greater cost than auto PDO accidents. This cost differential was applied to the accident costs recommended by the FHWA.[44]

The results of the cost analysis are presented in table 12. The average annual cost per mile for truck accidents was $182,000. For comparative purposes only the annual cost per mile for other vehicle accidents was $1,222,000 due to the greater frequency of other vehicle accidents than truck accidents.

Table 12. Summary of total accident costs for the analyzed urban freeway segments.

Vehicle Type	Total Accidents	No. of Deaths	Fatality Cost	Persons Injured	Injury Cost	PDO Accidents	PDO Cost	Total Cost For 3.75-Year Analysis Period (million dollars)	Annual Costs Per Mile[1] (thousand dollars)
Total Trucks	2,212	11	1,500,000	866	11,000	1,565	3,600	31.7	182
Passenger Vehicles	17,962	50	1,500,000	9,643	11,000	10,657	3,000	213.0	1,222

1 - Based on 46.5 miles of freeway.

DELAY COSTS

Vehicle delay was converted to an economic value by using data available from the AASHTO red book.[45] AASHTO provides low, medium, and high time saving estimates on the basis that small changes in travel time have little utility but as the time savings increase so does its utility and hence its economic value. The medium time savings was used and the given 1975 dollar value of $1.80 per traveler hour was increased to $3.60. This increase approximates the minimum wage level of current employment. This value was multiplied by 1.3 for every passenger vehicle to compensate for average vehicle occupancy. Similarly, the $7.50 per hour time savings for trucks was increased to $15.00 per truck hour but no occupancy factor was used.

The average delay of 14 minutes per vehicle per truck accident was applied to the same time of day divisions used to determine the traditional accident exposure. The results of the vehicle delay cost estimates are presented in table 13. The average annual delay cost per mile resulting from truck accidents was $440,000.

ACCIDENT CLEAN-UP COSTS

The clean-up costs resulting from truck accidents vary drastically and are difficult to determine. These costs vary according to the type of accident and cargo being transported. Truck accidents which are not major incidents do not have any clean-up costs which exceed those costs associated with other vehicle accidents. Accidents with cargo spillage, however, can entail very expensive clean-ups. Considering the magnitude of the other associated costs, however, the impact of the average clean-up cost does not have a major influence on the overall economic analysis. Caltrans estimated that the 6,700 to 8,000 annual truck accidents on the Los Angeles County freeway system cost in the range of $500,000 to 2 million for clean-up.[42] This estimate results in an approximate cost of $250 per accident and a total of $555,000 for the 2,221 investigated truck accidents.

Table 13. Annual delay cost per mile resulting from truck accidents on urban freeways.

				12 MD - 6 a.m. Truck Acc. = 129		6 a.m. - 12 NN Truck Acc. = 748		12 NN - 6 p.m. Truck Acc. = 1079		6 p.m. - 12 MD Truck Acc. = 265			
Vehicle Type	Time Value (hour)	Occupancy Factor	Average Delay (min/veh)	Volume	Period Delay (thousand hours)	Volume	Period Delay (thousand hours)	Volume	Period Delay (thousand hours)	Volume	Period Delay (thousand hours)	Total Delay Cost (million dollars)	Annual Delay Cost per mile[1] (thousand dollars)
Total Trucks	15.00	1	13.2	608	17.3	1,354	222.8	2,286	542.7	1,102	64.2	12.7	73
Passenger Vehicles	3.60	1.3	13.2	4,284	121.6	27,077	4,455.8	34,117	8,098.7	17,484	1,019.3	64.1	367
Totals												76.8	440

1 - Based on 46.5 miles of freeway and 3.75 years of data.

VEHICLE OPERATING COSTS

The primary component of vehicle operating costs due to truck accidents is related to increased fuel consumption resulting from delay and acceleration from the bottleneck speed to operating speed. The estimated increased operating cost of $947 was associated with 17.4 minutes of delay per affected vehicle.[42] This estimate was adjusted to reflect the project delay estimate of 13.2 minutes per affected vehicle to obtain an operational cost of $718 per truck accident This results in a total cost of 1.6 million dollars for the 2,221 investigated truck accidents.

TOTAL ECONOMIC COST OF TRUCK ACCIDENTS

An estimate of the total cost of truck accidents is presented in table 14. The accidents analyzed for this study indicate that the average annual cost per mile of urban freeways is $634,000 due to truck accidents. Expanding this annual per mile cost estimate the the 1,937 miles of Interstate and 560 miles of freeways, with volumes over 100,000 vehicles per day, that exist nationwide results in a total nationwide annual cost of 1.6 billion dollars due to truck accidents.[46] This annual estimate should be considered as approximate and interpreted with caution. The impact of major truck accidents which close all freeway lanes for a long period of time and require large clean-up costs can have a large impact on the total cost.

Table 14. Total cost of truck accidents.

Cost Component	Total Cost of 2,221 Accidents (million dollars)	Annual Costs per Mile[1] (thousand dollars)
Accident Costs	31.7	182
Delay Costs	76.8	440
Clean-up Costs	0.6	3
Operating Costs	1.6	9
Total		634

[1] - Based on 46.5 miles of freeway and 3.75 years of data.

CHAPTER 6 - OBSERVATIONS FROM PROJECT ACTIVITIES

This project concentrated on identifying freeway segments with active surveillance and monitoring systems in an effort to obtain accurate volume, truck mix, and flow description due to accident data. Contacts with the surveillance agencies prior to site selection resulted in the determination that the data was present in the format required but would require extraction from various sources. The actual data collection process, however, disclosed that this was not the case. Problems with vehicle detection loops, detection equipment unable to classify vehicles and the failure to log accident occurrence events through to normal freeway operation were encountered in each agency used for this project. Mention of these problems is not intended as a critism of the freeway surveillance units. Their primary responsibility is to monitor freeway actions and respond to accidents and incidents in such a manner as to increase safety, reduce delay, and improve progression. The agencies are effective in accomplishing these responsibilities and have neither the financial resources nor manpower required to provide the detailed operational data needed for research projects. The problems were mentioned to make future researchers aware that extra time and effort are required to obtain accurate data. These efforts can include obtaining 24-hour classification and volume counts, and working with the police departments on a sample basis to obtain lane closures and duration of bottlenecks resulting from accidents.

The use of computerized summaries alone does not provide sufficient accuracy to conduct an analysis of specific vehicle and/or facility types. A large number of accidents were identified by the computer search as involving trucks and occurring on the freeway that were erroneous. The most prevalent errors included accidents on surface arterials in the vicinity of freeways and the designation of vehicle type. Frequently vehicles that were coded as bobtails were actually tractor/trailer combinations in which the reporting officer neglected to denote the trailer type. Another identified common error was erroneously coding a straight truck with trailer as tractor/trailer combinations. For accuracy to be maintained in truck and facility type studies it is necessary to inspect the verbal description and pictorial accident representation on copies of the original accident report. When possible it is advantageous to verify the vehicle type through the vehicle identification number.

The accident reports used for this project also did not contain sufficient information to identify the type of double which was involved in the accident. Western, Rocky Mountain, turnpike, and the relatively new Canadian doubles all have different operational and stability characteristics. The impact of these characteristics on accident occurrence can be determined from few, if any, of the current accident records in the States in which the doubles operate.

The estimates of truck mix obtained from the quasi-induced exposure method indicated truck volumes that were lower than expected from the selected project freeway segments. This may indicate that the quasi-induced method does not provide reliable accident involvement ratios when used to analyze different vehicle types or it could indicate a possible reduction in truck traffic on weekends and holidays. If the latter condition is the actual case then volume based exposure measures could be under estimating the true magnitude of the truck accident rate.

CHAPTER 7 - SUMMARY OF RESULTS

Accidents occurring from January of 1985 through September of 1988 on 46.5 miles of urban freeway were inspected. A total of 2,221 accidents were verified, by the vehicle identification number and/or the description of the original accident report, as involving a truck over 10,000 lb gross vehicle weight. Information on these accidents were placed into a data base file to provide a homogeneous data base with the required format to address project needs. A total of 17,962 accidents involving only passenger vehicles were identified as occurring on the same freeway segments and during the same period. The results presented below are based on analyses of these data.

- More truck accidents occurred on Friday (468 of the 2,221 truck accidents or 21.1 percent) than any other day for all types of trucks combined. Tractor/semitrailers experienced a greater percentage of their accidents on Friday than any other day of the week.

- Straight trucks with trailers experienced 32.7 percent (55 of 168 accidents) of their accidents during wet road conditions. This exceeds the wet road surface accident experienced by any other truck-trailer combination.

- There were 212 single-vehicle truck accidents. Tractor/semitrailers experienced 74.1 percent (1,190 of 1,605 accidents) of their accidents occur as two-vehicle accidents.

- Tractor/semitrailers were involved in 68.9 percent of the 103 accidents with 4 or more vehicles. These accidents involved a total of 326 vehicles with one accident involving 16 vehicles. Straight trucks without trailers accounted for 17.5 percent of all the 4 or more vehicle accidents involving a total of 81 vehicles, the largest accident of which included seven vehicles.

- Cargo spillage occurred in 114 of the 2,221 accidents (5.1 percent). Tractor/semitrailers had the greatest incidence (66.7 percent or 76 of 114 accidents) of cargo spillage accidents. Tractor/semitrailers were the greatest contributers to incidents of fuel leakage and vehicle fire, although, both of these occurrences were relatively rare.

- Tractor/semitrailers and doubles had 52.5 percent (843 of 1,605 accidents) of their accidents occur as sideswipes. The largest percentage of straight-truck accidents occurred as rear-end accidents (43.0 percent or 211 of 491 accidents).

- For the 205 accidents, which occurred in a right-hand merge area, the truck was on the freeway, rather than the ramp, in 90.7 percent or 186 of the 205 accidents. Similarly, for those accidents which occurred in a right-hand exit area of the freeway the truck was on the freeway in 73.0 percent or 89 of the 122 accidents. This indicates that the truck was not the vehicle performing the merge maneuver when the merge accident occurred.

- Doubles had the highest fatality rate with an average of 21.7 fatalities per 1,000 accidents. Injury rate by straight trucks with trailers exhibited an average injury rate of 494.0 injuries per 1,000 accidents.

- Eleven persons were killed in the 2,221 accidents involving at least one truck. This results in an average of 5 persons killed for every 1,000 accidents involving at least one truck. For the 17,962 accidents involving other vehicles 39 persons were killed for an average of 2.2 persons per every 1,000 accidents. Similarly, the 2,221 accidents involving at least one truck injured 866 persons; while the 17,962 accidents involving other vehicles resulted in a total of 9,643 persons being injured. The resultant rates are 389.9 persons injured per 1,000 accidents involving at least one truck and 536.9 persons per 1,000 accidents involving passenger vehicles.

- An estimate of the total annual cost of urban freeway accidents was determined to be $634,000 per freeway mile. This cost consisted of accident costs of $182,000, delay costs of $440,000, clean-up costs of $3,000, and operating costs of $9,000 per freeway mile. Expanding this estimate to the 1,937 Interstate and 560 freeway miles with average daily traffic volumes of over 100,000 vehicles results in a nationwide annual cost of 1.6 billion dollars.

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