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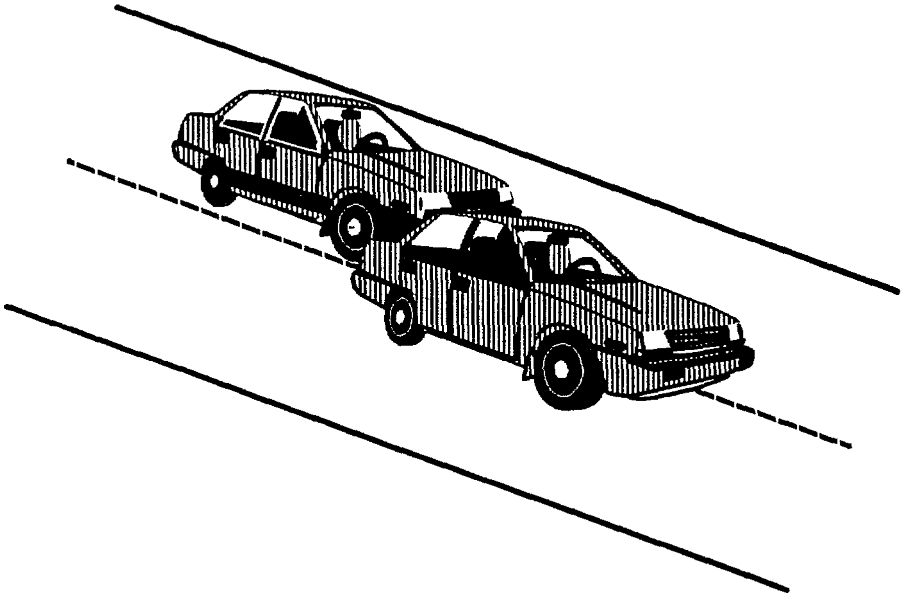
Lane Change/Merge Crashes: Problem Size Assessment and Statistical Description



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16. Abstract

This document presents problem size assessments and statistical crash descriptions for lane change/merge (LCM) crashes and two key subtypes of the LCM crashes. The LCM crashes are a potential "target crash" of high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. To elucidate potential countermeasure applicability, the LCM crash is divided into two types: angle/sideswipe and rear-end LCM crashes. The emphasis of this report is on the angle/sideswipe LCM crashes. This subclass is likely to be most amenable to prevention by an obstacle detection system. Principal data sources are the 1991 General Estimates System (GES) and Fatal Accident Reporting System (FARS). LCM crash problem size is assessed using such measures as number of crashes, number and severity of injuries, number of fatalities, crash involvement rate, and crash involvement likelihood. Problem size statistics are provided for four vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans), combination-unit trucks and medium/heavy sin le-unit trucks. Angle/sideswipe LCH crashes are described statistically primarily in terms of the conditions under which they occur (e.g., time of day, weather, roadway type, relation to junction) and, when data are available, in terms of possible contributing factors.

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EXECUTIVE SUMMARY

This document presents problem size assessments and statistical crash descriptions for lane change/merge (LCM) crashes. Principal data sources are the 1991 General Estimates System (GES) and Fatal Accident Reporting System (FARS). LCM crashes are potential "target crashes" of high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. For example, the proximity detection warning system concept (e.g., detection of obstacles iu the rear and lateral blind zone through the use of radar, ultrasound, or similar technologies) has been suggested as a possible countermeasure applicable to this crash type.

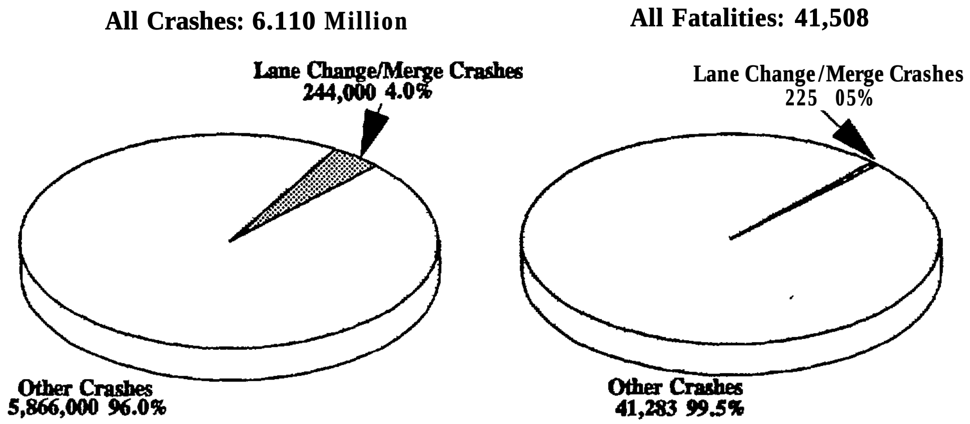
In this report, the LCM crash problem size is assessed using such measures as number of crashes, number and severity of injuries, number of fatalities, crash involvement rate, and crash involvement likelihood. Problem size statistics are provided for four vehicle type categories: all vehicles combined, passenger vehicles (i.e., cars, light trucks, light vans), combination-unit trucks, and medium/heavy single-unit trucks.

<u>Overall Problem Size</u>

Principal statistical findings regarding the LCM crash problem size include the following:

- In 1991, there were approximately 244,000 police-reported LCM crashes with 224 associated fatalities. Figure ES-1 illustrates the LCM crash and fatality statistics in relation to all crashes and crash fatalities.

FIGURE ES-1



- There were approximately 60,000 associated injuries, including 6,000 serious (incapacitating) injuries.

- Nevertheless, approximately 82.8 percent of 1991 LCM crashes were property-damage-only.

- LCM crashes constituted about 4.0 percent of all police-reported crashes, but accounted for only about 0.5 percent of all fatalities.

- During its operational life, a vehicle can be expected to be involved in 0.015 police-reported (PR) LCM crashes as the lane changing/merging vehicle.

- The above statistics relate to police-reported crashes. This report presents a method for estimating annual ***non-police reported*** (NPR) LCM crashes which yielded an estimate of approximately 386,000 for 1991.

- The report also presents a method for estimating crash-caused delay in vehicle-hours. Based on the estimation algorithm described in the report, LCM crashes cause about 9.1 percent of all crash-caused delay.

Lane Change/Merge Crash Type Taxonomv

Following the overall problem size assessment, this report disaggregates the overall problem into the two subtypes:

1. ***Angle/sideswipe*** LCM crashes.

2. ***Rear-end*** LCM in which the LCM vehicle is rear-ended after making the maneuver. These crashes typically crashes involve higher closing speeds then do the angle/sideswipe crashes.

The principal rationale for this taxonomy is potential countermeasure applicability. The angle/sideswipe LCM crashes appear to be generally applicable to the proximity detection countermeasure concept, whereas the applicability of rear-end LCM crashes to this countermeasure concept is more problematic.

Figure E-S-2 shows the relative crash problem sizes of these two crash subtypes.

FIGURE ES-2

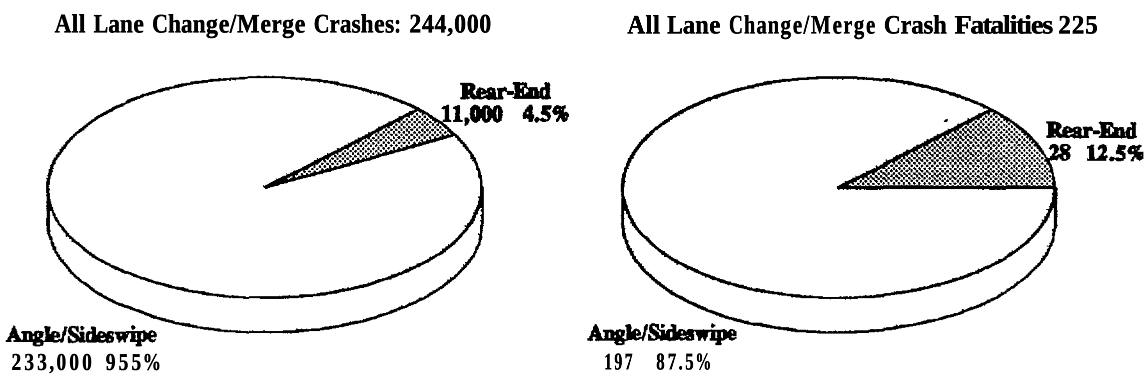


Figure ES-2 shows that of the estimated 244,000 LCM crashes in 1991, 233,000 (95 percent) were angle/sideswipe and 11,000 (5 percent) were rear-end LCM type. FARS statistics show that, of 225 LCM crash fatalities in 1991, 197 (88 percent) occurred in angle/sideswipe LCM crashes and 28 (12 percent) occurred in rear-end LCM crashes.

Crash Characteristics

The above statistics relate to all vehicle types combined. The report presents problem size statistics on angle/sideswipe LCM crashes for several major vehicle type categories, including passenger vehicles (here defined as cars, light trucks, and vans), combination-unit trucks (i.e., tractor-trailers), and single-unit medium/heavy trucks. For the three specific vehicle types, that vehicle type was involved as the subject vehicle (i.e., the lane changing/merging vehicle). In 1991, angle/sideswipe LCM crashes constituted 3.5 percent of passenger vehicle crashes, 9.2 percent of combination-unit crashes and 4.3 percent of single-unit truck crashes. Combination-unit truck types had rates of involvement (per 1,000 vehicle) and expected numbers of involvements that were far greater than that of passenger vehicles.

A comparison of vans versus other passenger vehicles which shows that there was little difference between the lane changing/merging vehicle involvements in angle/sideswipe LCM and other crash involvements (i.e., all other crash types). Annual involvements per 1,000 registered vehicles in this crash type is slightly higher for vans than for other passenger vehicles.

Descriptive statistics are also provided for angle/sideswipe LCM crashes only. Some notable statistical differences across the three vehicle types are apparent, even though crashes involving all three types occur largely during daytime with no adverse weather conditions or other major environmental contributing factors.

Angle/sideswipe LCM crash involvement rates (per 100 million VMT) were calculated for various driver age and sex groups. Involvement rates are highest for younger drivers, lowest for middle-aged drivers, and moderately high for older drivers. Overall, males have a slightly higher involvement rate (11.5 per 100 million vehicle miles traveled) than females (9.6) as the lane changing/merging vehicle driver.

The Indiana Tri-Level study (Treat et ***al,*** 1979) were accessed to provide in-depth causal factor analysis for LCM crashes. Nineteen (19) cases were identified. The Tri-Level statistics portray LCM crashes as resulting largely from driver recognition errors (e.g., delay recognition, improper lookout) and decision errors (e.g., false assumption and improper maneuver such as turned from wrong lane).

Appendices

Appendices to the report provide detailed definitions and explanations of all statistics used, statistics on all crashes (i.e., the "universe" of crashes), generalized estimated sampling errors for the 1991 GES, and reference citations.

1. INTRODUCTION

This document presents problem size assessments and statistical crash descriptions for lane change/merge (LCM) crashes and two major subtypes of LCM crashes. LCM crashes are potential "target crashes" of various high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. In this report, LCM crash problem size is assessed using such measures as number of crashes, number and severity of injuries, number of fatalities, crash involvement rate (per 100 million vehicle miles of travel), and crash involvement likelihood (e.g., annual number of involvements per 1,000 vehicles). LCM crashes are described statistically primarily in terms of the conditions under which they occur (time, day, weather, roadway type, etc.) and, when data are available, in terms of possible contributing factors.

This problem size assessment and statistical description of LCM crashes has been prepared in conjunction with an ongoing analytical process intended to determine the extent to which high-technology IVHS devices -- and more conventional countermeasures -- can be employed effectively to prevent (and lessen the severity of) crashes, including LCM crashes. This related analytical countermeasure modeling work is described in a technical report by Chovan et *al* (1993). The principal countermeasure concept examined by Chovan et *al* is a object proximity detection system that would detect vehicles adjacent to the equipped vehicle, especially in the area do the drivers lateral "Blind Zone".

This document provides statistics on current LCM crash problem size, the conditions of occurrence and, to a limited extent, the causes of LCM crashes. Most statistics provided are estimates based on national crash databases, such as the 1991 NHTSA General Estimates System (GES). Applicable crash fatality counts from the 1991 Fatal Accident Reporting System (FARS) are also presented. Both GES and FARS statistics address ***only police-reported*** crashes, although a rough estimate of the non-police-reported LCM crash population is provided based on a new estimation procedure for these crashes.

The provision of crash statistics for LCM crashes and other topics implies that the crash problem in question can be stated and quantified in terms of existing database variables/elements to an acceptable degree of accuracy. In practice, accuracy will vary, based primarily on how well crash database variables and definitions correspond to the target crash type as delimited by the action of the conceived countermeasure. In some cases, a problem size assessment may represent a target crash type that is broader, narrower, or otherwise different than that conceptualized according to the action of the countermeasure on driver or vehicle response. Thus, baseline problem size assessments may be modified based on additional information as part of the more comprehensive problem definition/countermeasure technology assessment process. In the case of LCM crashes, the report will initially present the entire LCM crash population and then disaggregate the overall problem into two subtypes: angle/sideswipe and ***rear-end LCM.*** The countermeasure analytical modeling work described above (Chovan et ***al, 1993)*** addresses these two subtypes separately (with emphasis on the angle/sideswipe subtype), thus necessitating separate statistical analyses.

In summary, the crash problem statistics presented in this report are intended to be compatible with ongoing countermeasure modeling/effectiveness estimation efforts. This information supports the assessment of potential safety benefits of crash prevention approaches and also helps to define the conditions under which countermeasures must operate in order to be effective.

The remainder of this report is organized as follows:

- Chapter 2 disaggregates the LCM crash problem size into two major subtypes: angle/sideswipe and rear-end LCM. Chapter 2 then provides a definition (per major NHTSA crash databases) and presents problem size statistics on these subtypes.

- Chapter 3 provides descriptive statistics regarding angle/sideswipe LCM crashes. This includes crash involvement rates for various driver age and sex groups.

- Chapter 4 recounts statistics from the Indiana Tri-Level study on the causes of LCM crashes.

- Appendix A defines and describes the derivation of statistics used to quantify and describe the LCM and other target crash problems.

- Appendix B provides a problem size assessment for ***all*** crashes, the "universe" of the U.S. crash problem, in accordance with the above statistical measures.

- Appendix C is a technical note explaining GES sampling errors and providing tables of GES standard errors of estimate.

- Appendix D is reference section listing publications cited or otherwise relevant to this report.

2. LANE CHANGE/MERGE CRASH PROBLEM SIZE

This chapter presents problem size assessment for lane change/merge (LCM) crashes. For the purpose of analysis, LCM crashes have been disaggregated into two different subtypes: ***angle/sideswipe*** and rear-end LCM crashes. Figure 2-1 shows four LCM crash configuration. Three of these would be classified angle/sideswipe; the fourth would be rear-end. Usually, angle/sideswipe LCM crashes involve two or more vehicles with similar speeds; they are potentially addressable by high-technology countermeasures such as lateral proximity warning systems. A rear-end LCM crash is one in which the subject vehicle is rear-ended after making the maneuver. In LCM crashes, the non-LCM vehicle is generally traveling at a higher speed than the LCM vehicle. Thus, the other vehicle would often not enter the a lateral blind zone detection area of a lateral proximity warning system or would be closing too fast for such a warning to enable a driver to react to avoid a crash. Therefore, this chapter will put more emphasis on angle/sideswipe LCM crashes because they appear to be more addressable by available countermeasures.

Note that crashes in which a vehicle is rear-ended while waiting to make a merge or lane change are not addressed in this report. This common crash scenario is included in the rear-end crash type (see Knipling, Wang and Yin, 1993). Also included in the rear-end crash type are crashes where a subject vehicle (i.e. LCM vehcile) strikes the rear of another vehicle.

This chapter is divided into three major sections:

2.1 Overall Problem Size.

2.2 Angle/Sideswipe Lane Change/Merge Crashes

2.3 Rear-End Lane Change/Merge Crashes.

All statistics regarding crashes and non-fatal injuries presented in Table 2-1, 2-2 and 2-3 are rounded to nearest 1,000. The "subject vehicle" in all three tables is the lane changing/merging vehicle, although in a small proportion of cases there is more than one subject (i.e. lane changing/merging) vehicle per crash. The reader may refer to Appendix A for explanations of the statistical metrics used.

2.1 Overall Problem Size

This section presents an overall problem size assessment for all LCM crashes (i.e., angle/sideswipe and rear-end LCM combined). GES statistics encompass all multiple vehicle crashes involving a vehicle with Imputed Vehicle Maneuver (V2II, MANEUV_I) 14 (changing lanes or merging). FARS statistics encompass all fatal crashes involving a vehicle with the Vehicle Maneuver (VEH_MAN) 16 (changing lane and merging).

FIGURE 2-l. Four Lane Change/Merge Crash Configurations

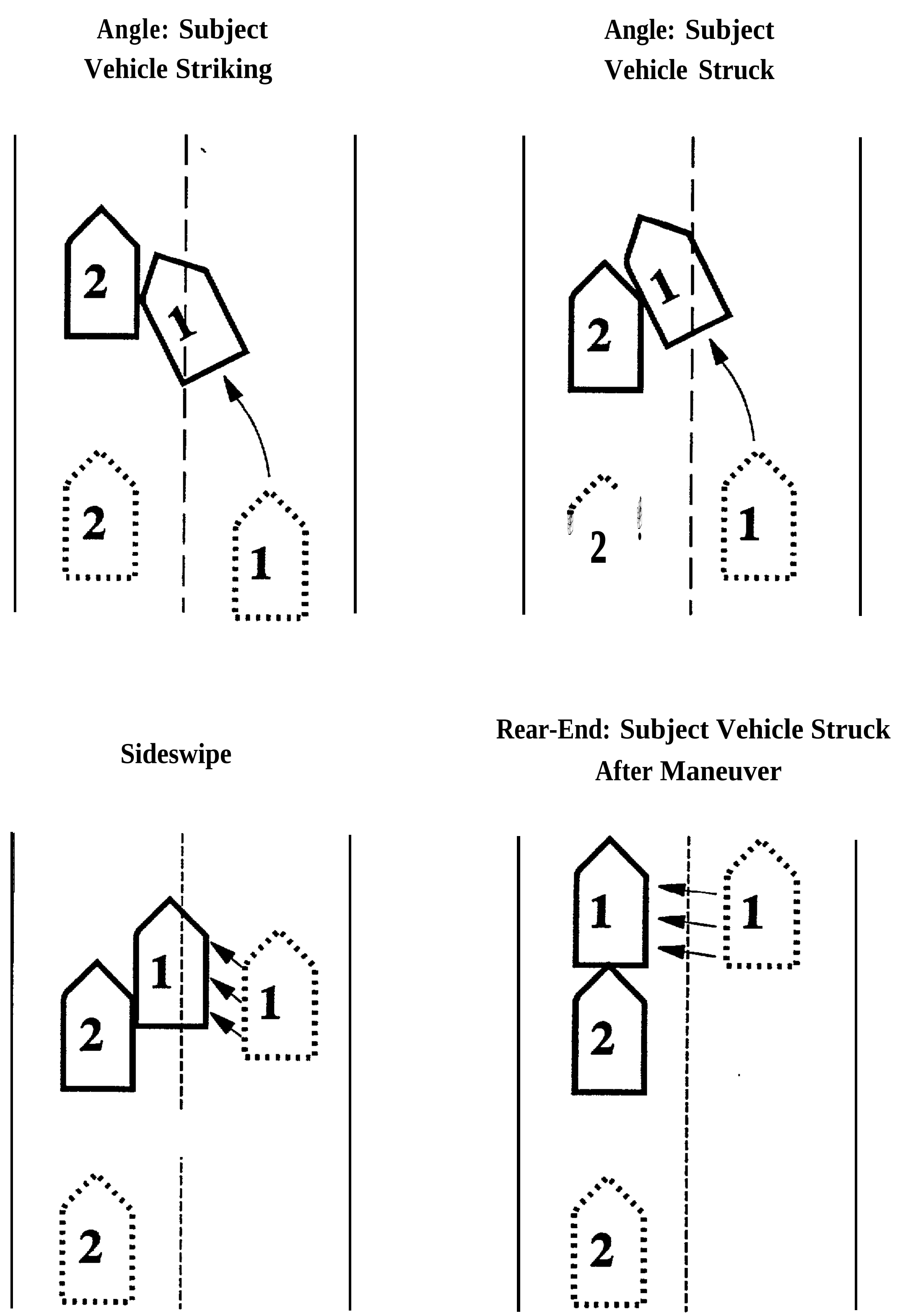
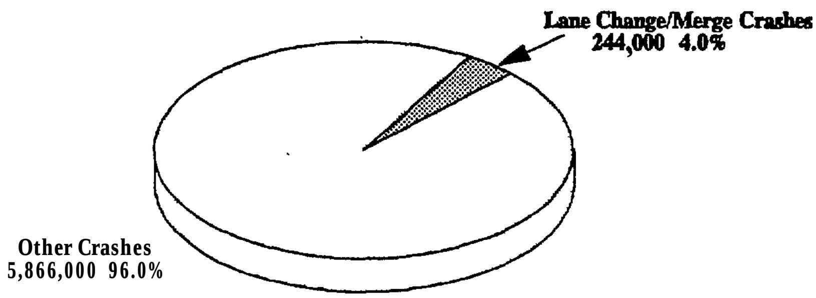


Table 2-1 shows the following:

- There were 244,000 LCM crashes (Standard Error = 19,000), which constituted 4.0 percent of all police-reported crashes. See Figure 2-2.

FIGURE 2-2

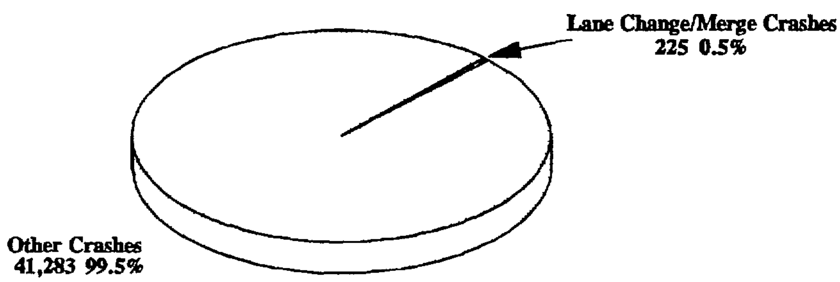
All Crashes: 6.110 Million



a There were 225 fatalities, which constituted 0.5 percent of all fatalities. See Figure 2-3.

FIGURE 2-3

All Fatalitites: 41,508



- LCM crashes were associated with approximately 1,318 fatal crash equivalents (see Appendix A for definition).

- About 82.8 percent of target crashes were property damage only.

- The involvement rate as the subject (lane changing/merging) vehicle is 11.6 involvements per 100 million vehicle miles traveled.

- The expected number of involvements (as the subject vehicle) during a vehicle operational life is 0.0171. Since this proportion is small, it may be interpreted directly as a probability - i.e., about 1.7 percent of vehicles will be involved in a target crash as the subject vehicle.

TABLE 2-1
PROBLEM SIZE STATISTICS FOR ALL LANE CHANGE/MERGE CRASHES
INVOLVED VEHICLE TYPES: ALLVEHICLES

GES/FARs-Based Statistics (1991)		*All* *Lane* Change/Merge Crashes
Annual # PR Crashes (GES)	**Total:**	244,000
	Injury:	42,000
	PDO:	202,000
Annual # Fatalities (FARS)		225
Ann. # Non-Fatal PR Injuries (GES)	**Total:**	60,000
	A:	6,000
	B:	13,000
	C:	41,000
Fatal Crash Equivalents (FCEs)		1,318
Percentage of All PR Crashes		4.00%
Percentage of All FCE		1.43%
Percentage of All Fatalities		0.54%
Involvements as "Subject (Lane Changing/Merging) Vehicle":		
Involvement Rate Per 100 Million VMT		11.6
Annual Involvements Per 1,000 Registered Vehicles		1.30
Expected # Involvements During Vehicle Life		0.0171
Estimated Annual # NPR Crashes	**Total:**	386,000
	Injury:	46,000
	PDO:	340,000
Estimated Total Annual Target Crashes (PR + NPR)	**Total:**	630,000
	UDH:	226,000
	Non-UDH:	403,000
Crash-Caused Congestion (Delay)	**Veh-Hours:**	41.2 M
Percentage of All Crash-Caused Delay		**9.15%**

Legend:

A	Incapacitating Injuries	M	Million
B	Nonincapacitating Injuries	NPR	Non-Police Reported
C	Possible Injuries	PDO	Property Damage Only
FARS	Fatal Accident Reporting System	PR	Police Reported
FCE	Fatal Crash Equivalent	UDH	Urban Divided Highway
GES	General Estimates System	VMT	Vehicle Miles Traveled

2.2 Angle/Sideswipe Lane Change/Merge Crashes

Angle/sideswipe LCM crashes were defined as follows in GES and FARS:

GES Estimates (1991) (Note: The reader is referred to the 1991 GES User's Manual for definition and explanation of the following data variables.):

Imputed Vehicle Maneuver (V21I, MANEUV_I) = 14 (Changing Lanes or Merging)

Imputed Vehicle Role (V22I, VROLE_I) = 1 (Striking)
= 2 (Struck)
= 3 (Both Striking and Struck)

Involved Vehicles per Crash (A3, VEH_INVL) $\geq$ 2 (2 or More Vehicles per Crash)

Imputed Manner of Collision (A7I, MANCOL_I) = 4 (Angle)
= 5 (Sideswipe, Same Direction)

FARS Estimates (1991) (Note: The reader is referred to the 1991 FARS Coding and Validation Manual for definition and explanation of the following data variables.):

Vehicle Maneuver (VEH_MAN) = 16 (Changing Lanes or Merging)

Vehicle Role (IMPACTS) = 1 (Striking)
= 2 (Struck)
= 3 (Both Striking and Struck)

Number of Vehicle Forms Submitted (VE_FORMS) $\geq$ 2 (2 or More Vehicles per Crash)

Manner of Collision (MAN-COLL) = 4 (Angle)
= 5 (Same-Direction Sideswipe)

2.2.1 Problem Size Statistics

Table 2-2 presents 1991 statistics for the angle/sideswipe LCM crashes for all vehicle types, passenger vehicles, combination-unit trucks and single-unit trucks. For the three specific vehicle types, that vehicle type was involved as the subject vehicle (i.e., the lane changing/merging vehicle). Table 2-2 shows the following:

- Approximately 233,000 angle/sideswipe LCM crashes were reported by police in 1991 (Standard Error = 18,500). This constituted 3.8 percent of all police-reported crashes and 96.7 percent of police-reported all LCM crashes.

- There were 197 associated fatalities and approximately 56,000 non-fatal police-reported injuries (Standard Error = 5,000) resulting from angle/sideswipe LCM crashes.

- Target crashes were associated with 1,318 fatal crash equivalents.

- Target crashes constituted:
  - 1.4 percent of total fatal crash equivalents
  - 0.5 percent of the total crash fatalities.

- The involvement rate as the subject (lane changing/merging) vehicle is 11.1 involvements per 100 million vehicle miles traveled.

- The expected number of involvements (as the subject vehicle) during a vehicle operational life is 0.0164. Since this proportion is small, it may be interpreted directly as a probability - i.e., about 1.6 percent of vehicles will be involved in a target crash as the subject vehicle.

- Target crashes caused roughly 8.6 percent of all crash-caused delay.

2.2.2 Passenger Vehicles Versus Medium/Heavy Trucks

Table 2-2 shows comparable statistics on angle/sideswipe LCM crashes for three different vehicle tyes: passenger vehicles (car, light truck, light van), combination-unit trucks, and single-unit trucks. Table 2-2 indicates that:

- In terms of absolute number of involvements in target crashes (as the subject vehicle, i.e. LCM vehicle), there were far more passenger vehicle involvements (208,000) in 1991 than combination-unit truck (18,000) or single-unit truck (6,000) involvements.

TABLE 2-2
PROBLEM SIZE STATISTICS FOR *ANGLE/SIDESWIPE* LANE CHANGE/MERGE CRASHES INVOLVED VEHICLE TYPES: ALL VEHICLES, PASSENGER VEHICLES, COMBINATION-UNIT TRUCES AND SINGLE-UNIT TRUCKS

;ES/FARS-Based Statistics (1991)		*All* Vehicles	Passenger Vehicles	Combination-Unit Trucks	Single-Unit Trucks
Annual # PR Crashes (GES)	Total:	233,000	208,000	18,000	6,000
	Injury:	39,000	33,000	4,000	1,000
	PDO:	195,000	176,000	13,000	5,000
Annual # Fatalities (FARS)		197	173	19	0
Ann. # Non-Fatal PR Injuries *(GES)*	Total:	56,000	48,000	5,000	1,000
	A:	5,000	4,000	1,000	0
	B:	12,000	10,000	1,000	0
	C:	38,000	34,000	3,000	1,000
Fatal Crash Equivalents (FCEs)		1,318	1,000	128	21
Percentage of AU PR Crashes		3.82%	3.49%	9.22%	4.30%
Percentage of AU FCE		1.43%	1.16%	2.86%	1.06%
'ercentage of All Fatalities		0.47%	0.45%	052%	0.00%
Involvements as "Subject Vehicle"*:					
involvement Rate Per 100 Million VMT		11.1	10.7	18.1	10.4
Annual Involvements Per 1,000 Registered Vehicles		1.25	1.18	10.94	1.32
Expected # Involvements During Vehicle Life		0.0164	0.0153	0.1608	0.0193
Estimated Annual # NPR Crashes	Total:	371,000	335,000	25,000	9,000
	Injury:	44,000	40,000	3,000	1,000
	PDO:	327,000	295,000	22,000	8,000
Estimated Total Annual Target Crashes (PR + NPR)	Total:	605,000	543,000	43,000	15,000
	UDH:	214,000	180,000	26,000	6,000
	Non-UDH:	391,000	363,000	17,000	9,000
Crash-Caused Congestion (Delay)	Veh-Hours:	38.9 M	32.8 M	4.8 M	1.1 M
Percentage of All Crash-Caused Delay		8.64%	7.29%	1.07%	0.24%

* Subject Vehicle = Vehicle changing lanes or **merging.** In 97.1 percent of crashes, there is one subject vehicle. In 2.9 percent there are two subject vehicles (e.g. both changing lanes).

Legend:

A	Incapacitating Injuries
B	Nonincapacitating Injuries
C	Possible Injuries
FARS	Fatal Accident Reporting System
FCE	Fatal Crash Equivalent
GE-S	General Estimates System
M	Million
NPR	Non-Police Reported
PDO	Property Damage Only
PR	Police Reported
UDH	Urban Divided Highway
VMT	Vehicle Miles Travel

- Target crash involvements as the subject (LCM) vehicle constituted a larger percentage of all crashes for combination-unit trucks (9.2 percent) than for single-unit trucks (4.3 percent) and passenger vehicles (3.5 percent).

- Based on vehicle miles of travel, combination-unit trucks had the highest target crash involvement rate (18.1 per 100 million VMT) as the subject vehicle, compared to 10.7 for passenger vehicles, and 10.4 for single-unit trucks.

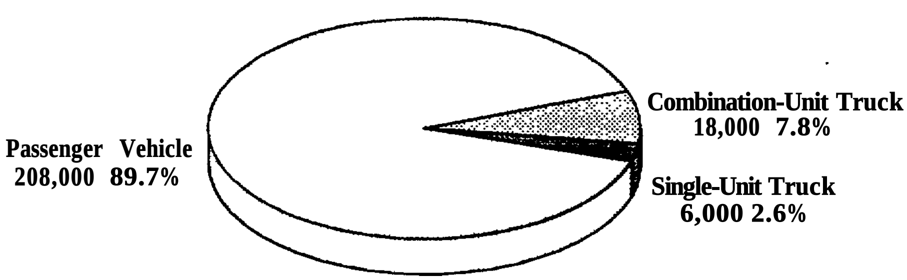
- Per 1,000 combination-unit trucks during 1991, there were 10.9 angle/ sideswipe LCM crash involvements (as the subject vehicle), versus 1.3 per 1,000 single-unit trucks and 1.2 per 1,000 passenger vehicles.

- Based on an extrapolation of these 1991 statistics, the expected number of LCM crash involvements during a combination-unit truck life time is 0.1608, which is ten times the value for passenger vehicles (0.0153) and eight times the value for single-unit trucks (0.0193).

Appendix A contains definitions and explanations of the statistical metric "involvement rate" and the two "likelihood" metrics used above: 1) Involvements per 100 registered vehicles and 2) Expected number of involvements over vehicle life.

In summary, the above statistics show that target passenger vehicle crashes are far more numerous than target truck crashes, but that combination-unit trucks have a higher rate and are far more *likely* to be involved in target crashes than are passenger vehicles or single-unit trucks. Figures 2-4, 2-5, and 2-6 present a graphic overview of these key comparisons. All are based on subject vehicle (i.e., LCM vehicle) involvements only.

FIGURE 2-4
Angle/Sideswipe LCM Crash Involvements (As Subject Vehicle) by Vehicle Type



All Angle/Sideswipe LCM Crashes: 233,000

FIGURE 2-5
Angle/Sideswipe LCM Crash Involvement Rate (per 100M VMT) by Vehicle Type

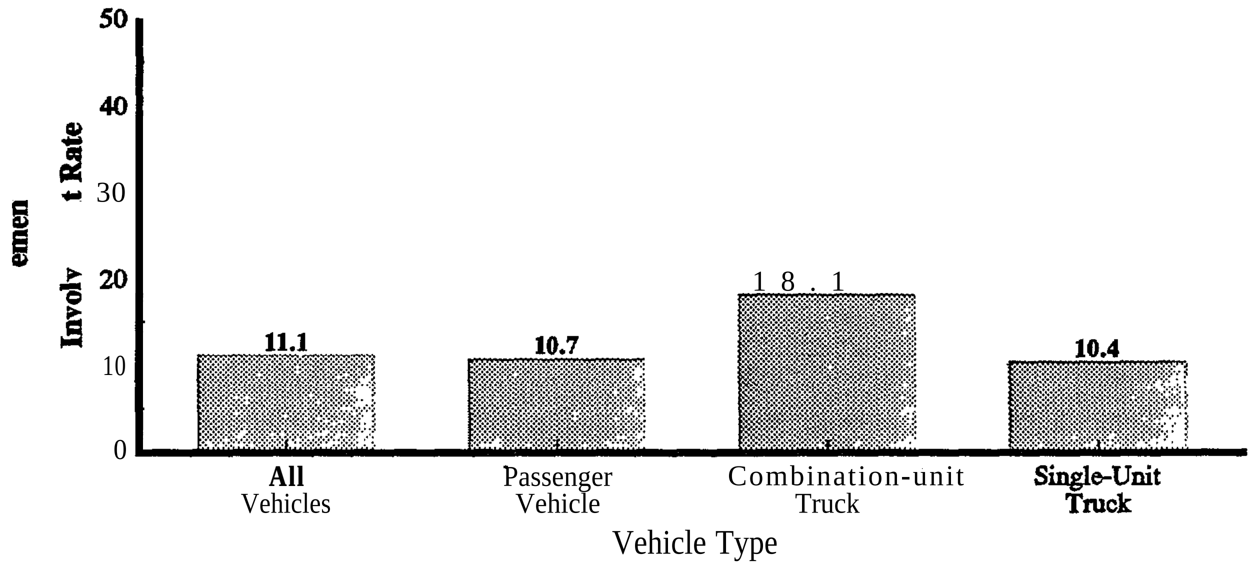
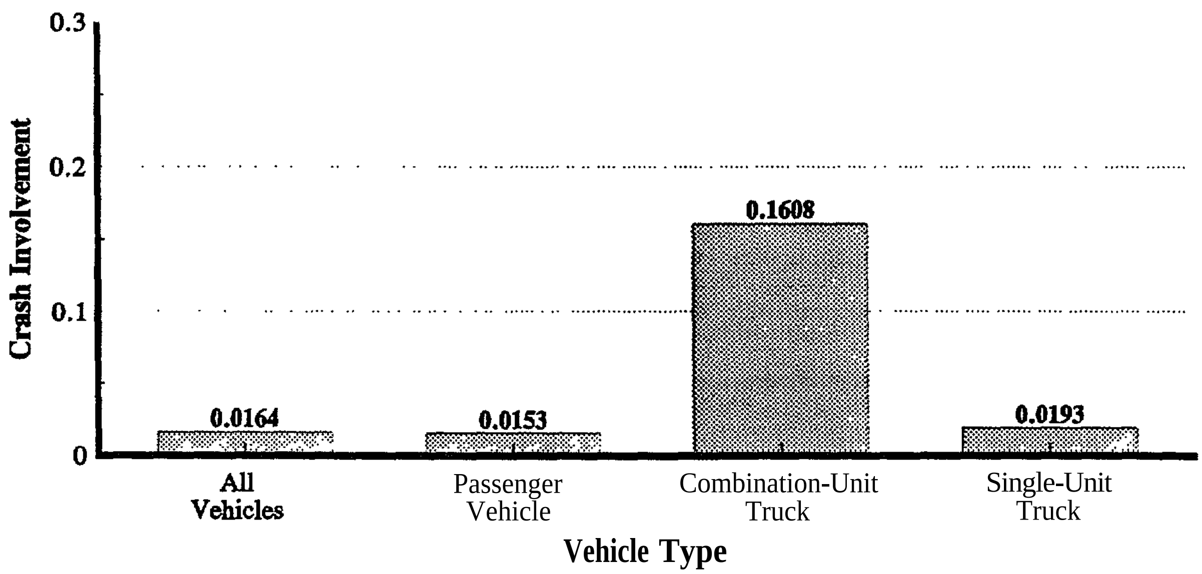


FIGURE 2-6
Expected Number of Angle/Sideswipe LCM Crash Involvements Over Vehicle Operational Life by Vehicle Type



2.2.3 Vans Versus Other Passenger Vehicles

Compared to other passenger vehicles (i.e. cars, light trucks), the lateral visibility of vans is often limited. Thus the question arises as to whether vans are overrepresented in angle/sideswipe LCM crashes (as the subject vehicle). However, lack of readily-available and reliable mileage data prevented the calculation of involvement rates as presented in previous tables. Therefore, only relative crash frequency distributions and likelihood statistics for these two vehicle, types -- vans and passenger vehicles other than vans -- are presented here. **Table 2-3** presents overall involvements in angle/sideswipe LCM crashes (lane changing/merging vehicle) against involvements in all other crashes. As can be seen in Table 2-3, the percentage of vans involved in these crashes (as the subject vehicle) was slightly lower than the percentage of their involvement (regardless of their role in the crashes, i.e., striking or struck) in other crashes.

TABLE 2-3
CRASH DISTRIBUTION
OTHER PASSENGER VEHICLES VERSUS VANS

Vehicle Type	Angle/Sideswipe Lane Change/Merge Crashes	Other Crashes
Passenger Vehicles (other than vans)	91.5%	91.0%
Vans	8.5%	9.0%
Total	100.0%	100.0%

(Note: The column percentages for angle/sideswipe LCM crashes in Table 2-3 are percentages of the involved subject vehicles as the lane changing/merging vehicle. But for the column of other crashes, the percentages represent the distribution of involved vehicles regardless of vehicle role.)

Table 2-4 shows that the annual involvement in LCM crashes per 1,000 registered vehicles is slightly higher for vans than for other passenger vehicles.

TABLE 2-4
ANGLE/SIDESWIPE LANE CHANGE/MERGE CRASHES
OTHER PASSENGER VEHICLES VERSUS V-S

Vehicle Type	Annual Involvements per 1,000 vehicles
Passenger Vehicles (other than vans)	1.25
Vans	1.69

(Note: Highway Statistics (published by FHWA) lacks van registration information. Therefore, vehicle registrations in the National Vehicle Population Profile data base (copyright R.L. Polk & Co.) **were used** here to calculate annual involvements per 1,000 vehicles.)

2.3 Rear-End Lane Change/Merge Crashes

Rear-end LCM crashes were defined as follows in GES and FARS:

GES Estimates (1991) (Note: The reader is referred to the 1991 GES User's Manual for definition and explanation of the following data variables.):

Imputed Vehicle Maneuver (V2lI, MANEUV_I) = 14 (Changing Lanes or Merging)

Imputed Vehicle Role (V22I, VROLE_I) = 2 (Struck)

Involved Vehicles per Crash (A3, VEH_INVL) $\geq$ 2 (2 or More Vehicles per Crash)

Imputed Manner of Collision (A7I, MANCOL_I) = 1 (Rear-End)

FARS Estimates (1991) (Note: The reader is referred to the 1991 FARS Coding and Validation Manual for definition and explanation of the following data variables.):

Vehicle Maneuver (VEH_MAN) = 16 (Changing Lanes or Merging)

Vehicle Role (IMPACTS) = 2 (Struck)

Number of Vehicle Forms Submitted (VIZ-FORMS) $\geq$ 2 (2 or More Vehicles per Crash)

Manner of Collision (MAN-COLL) = 1 (Rear-End)

Rear-end crashes where the lane changing/merging vehicle was striking were not included because it was presumed that in these crashes the struck vehicle was seen pre-crash. Thus, they seem to represent a separate crash category from a causal perspective.

All the problem size statistics presented on Table 2-5 are based on a non-weighted sample size of 82 crashes. Because of small sample size, the significant of statistics will be affected. Table 2-5 indicates:

- Approximately 11,000 rear-end LCM crashes were reported by police in 1991 (Standard Error = 2,220), which constituted 0.2 percent of all police-reported crashes and 3.3 percent of police-reported all LCM crashes.

TABLE 2-5
PROBLEM SIZE STATISTICS FOR REAR-RND LANE CHANGE/MERGE CRASHES
INVLOVED VEHICLE TYPES: ALL VEHICLES

GES/FARS-Based Statistics (1991)		*All* Vehicles
Annual # PR Crashes (GES)	Total:	11,000
	Injury:	3,000
	PDO:	8,000
Annual # Fatalities (FARS)		28
Ann. # Non-Fatal PR Injuries (GES)	Total:	4,000
	A:	1,000
	B:	1,000
	c:	3,000
Fatal Crash Equivalents (FCEs)		113
Percentage of All PR Crashes		0.17%
Percentage of All FCE		0.12%
Percentage of All Fatalities		0.07%
Involvements as "Subject Vehicle":		
Involvement Rate Per 100 Million VMT		0.5
Annual Involvements Per 1,000 Registered Vehicles		0.06
Expected # Involvements During Vehicle Life		0.0007
Estimated Annual # NPR Crashes	Total:	14,000
	Injury:	2,000
	PDO:	12,000
Estimated Total Annual Target Crashes (PR + NPR)	Total:	25,000
	UDH:	12,000
	Non-UDH:	13,000
Crash-Caused Congestion (Delay}	Veh-Hours:	2.3 M
Percentage of All Crash-Caused Delay		0.51%

Legend:

A	Incapacitating Injuries	M	Million
B	Nonincapacitating Injuries	NPR	Non-Police Reported
C	Possible Injuries	PDO	Property Damage Only
FARS	Fatal Accident Reporting System	PR	Police Reported
FCE	Fatal Crash Equivalent	UDH	Urban Divided Highway
GES	General Estimates System	VMT	Vehicle Miles Travel

- There were 28 associated fatalities and approximately ***4,000*** non-fatal police-reported injuries (Standard Error = 880) resulting from rear-end LCM crashes.

- In 1991, rear-end LCM crashes were associated with 113 fatal crash equivalents.

- Rear-end LCM crashes caused roughly 0.5 percent of all crash-caused delay.

3. ANGLE/SIDESWIPE LANE CHANGE/MERGE CRASH DESCRIPTIVE STATISTICS

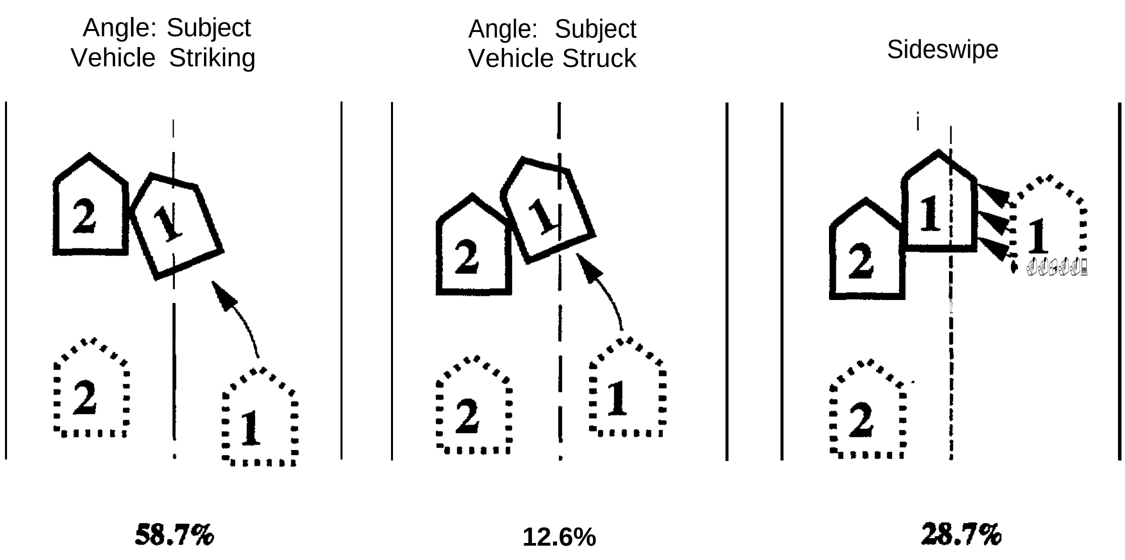
Angle/sideswipe lane change/merge (angle/sideswipe LCM) crashes can be categorized into three basic configurations, based on the manner of collision of the lane changing/merging (subject) vehicle and its role. They are:

- Angle: subject vehicle was striking
- Angle: subject vehicle was struck and,
- Sideswipe: subject vehicle is either striking, struck or both.

Figure 3-1 shows the percentage distribution of these three configurations. More than 50 percent of the angle/sideswipe LCM crashes were angle LCM, the subject vehicle was striking, 30 percent were sideswipe LCM, and 13 percent were angle LCM, the subject vehicle was struck.

This chapter is going provide descriptive statistics to describe overall angle/sideswipe LCM crashes but not to a specific configuration.

FIGURE 3-l. Angle/Sideswipe LCM Crashes



3.1 Statistics Using GES Data

GES bivariate distributions were obtained from 1991 GES to describe angle/sideswipe LCM crashes. All descriptive statistics were categorized into three vehicle types: all vehicle types combined, passenger vehicles, and combination-unit trucks. Imputed and ***Hotdeck imputed*** GES variables were used if available (i.e., variables where unknowns were distributed proportionately across known values). Statistics relating to the following variables were obtained:

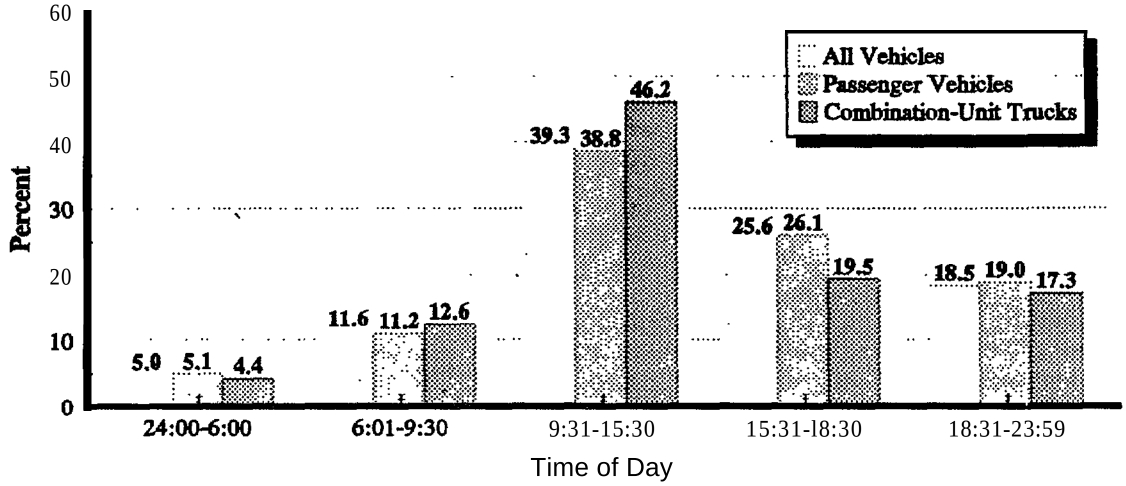
Imputed Time Blocks (i.e., 24:00-06:00); 06:01-09:30; 09:31-15:30; 15:31-18:30; 18:31-23:59)
Imputed Day of Week (AlCI, WKDY_I)
Land Use (AO5, LAND-USE)
Percent Rural (A5A, RUR_URB)
Imputed Relation to Junction (AO9I, RELJCT_I)
Trafficway Flow (Al 1, TRAF-WAY)
Imputed Roadway Profile (A14I, PROFIL_I)
Imputed Roadway Surface Condition (Al5I, SURCON_I)
Hotdeck Imputed Speed Limit (Al8I, SPDLIM_H)
Imputed Light Condition (A19I, LGTCON_I)
Imputed Atmospheric Condition (A20I, WEATHR_I)
Imputed Violations Charged (D2I, VLTN_I) to Driver of subject vehicle (with Imputed Vehicle Maneuver [V21I, MANEUV_I] = 14)
Driver's Vision Obscured By . . . (DO4, VIS_OBSC) for Driver of subject vehicle (with Imputed Vehicle Maneuver [V21I, MANEUV_I] = 14)
Driver Distracted By . . . (DO7, DR_DSTRD) for Driver of subject vehicle (with Imputed Vehicle Maneuver [V21I, MANEUV_I] = 14)
Hotdeck Imputed Initial Point of Impact (V24H, IMPACT-H)
Hotdeck Imputed Driver's Age (P7H, AGE_H) of Driver of subject vehicle (with Imputed Vehicle Maneuver [V21I, ***MANEUV_I] =*** 14)
Hotdeck Imputed Driver's Sex (P8H, SEX_H) of Driver of subject vehicle (with Imputed Vehicle Maneuver [V21I, ***MANEUV_I] =*** 14)

The following major findings are noted. For each specific variable (whether imputed or non-imputed), the percentage cited here is the proportion of known values.

- Time of Day

  About 76.5 percent of the angle/sideswipe LCM crashes occurred during daytime hours (06:0l to 18:30). See Figure 3-2.

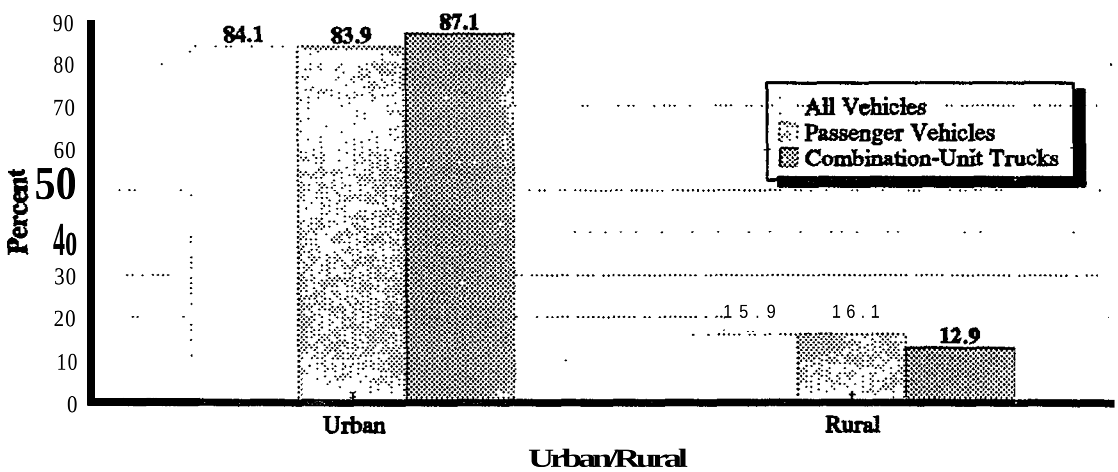
FIGURE 3-2. Angle/Sideswipe LCM Crashes by Time of Day



Urban/Rural

About 84.1 percent of angle/sideswipe LCM crashes occurred in urban areas. **Figure** 3-3 indicates that there is little difference between combination-unit truck and passenger vehicle involvements as subject vehicle.

FIGURE 3-3. Angle/Sideswipe LCM Crashes by Urban/Rural



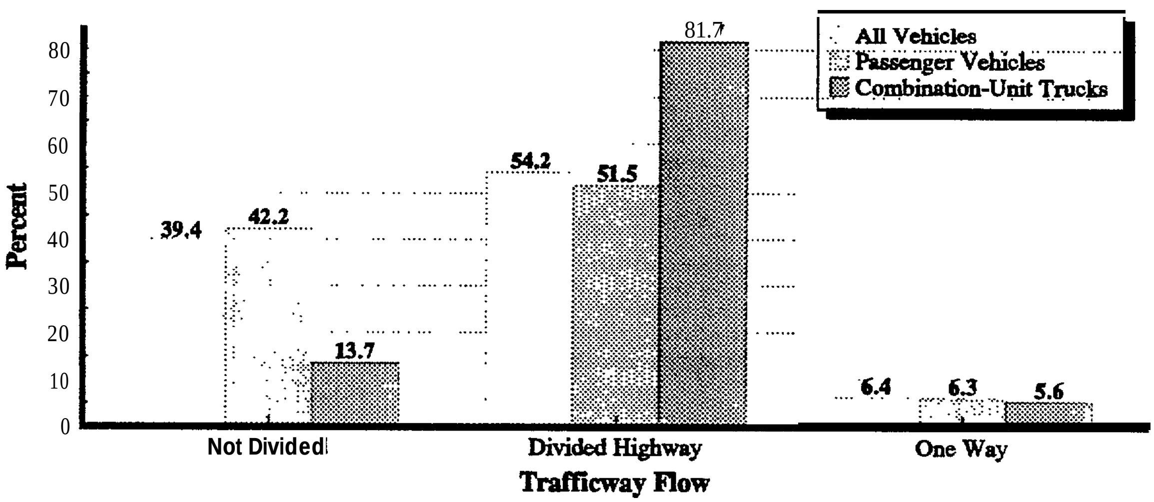
- **Relation to Intersection**

  About 68.2 percent were non-junction crashes, implying that these were primarily "lane change" rather than "merge" crashes. The non-junction percentage for combination-unit trucks (85.1 percent) as higher than that for passenger vehicles (66.9 percent).

- **Trafficway Flow**

  More crashes occurred on divided (54.2 percent) than undivided (39.4 percent) roadways. For combination unit trucks as subject vehicles, 81.7 percent occurred on divided highways. See Figure 3-4.

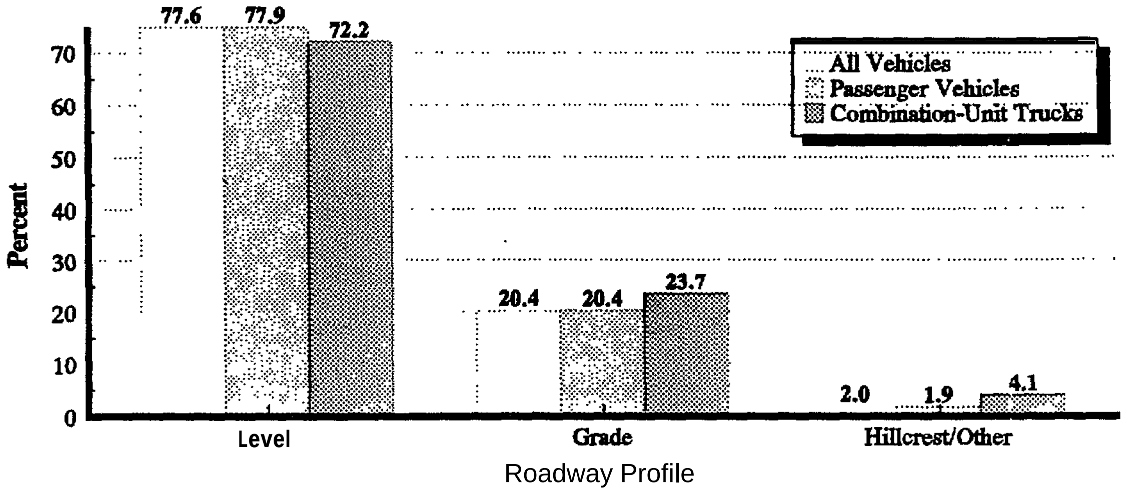
FIGURE 3-4. Angle/Sideswipe LCM Crashes by Trafficway Flow



- Roadway Profile

  Figure 3-5 shows that about 77.6 percent of the target crashes occurred on level roadways and 20.4 percent occurred on grades.

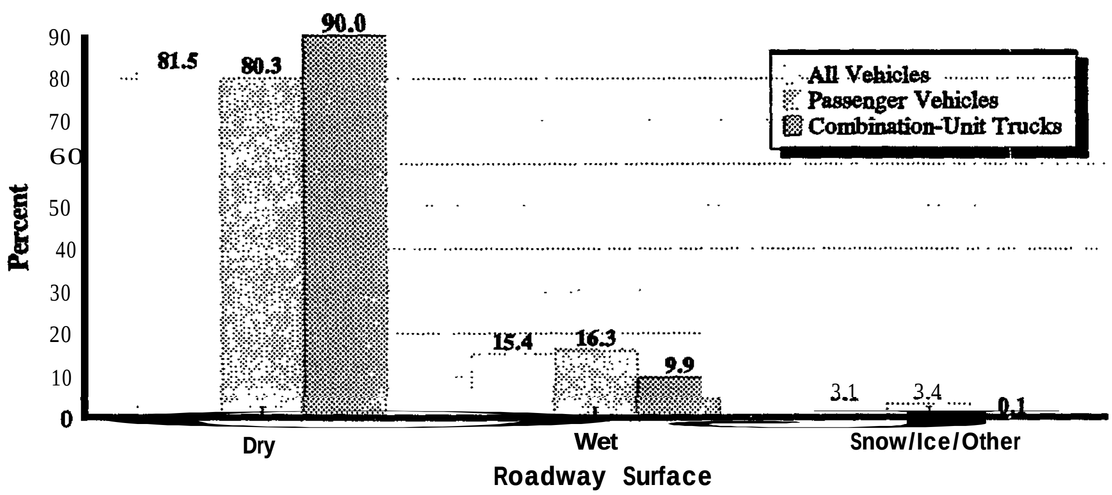
FIGURE 3-5. Angle/Sideswipe LCM Crashes by Roadway Profile



- **Roadway Surface Conditions**

Overall, 81.5 percent of target crashes occurred on dry roadways, 15.4 percent on wet roadways. The percentage of crashes occurring on wet roadways was higher for passenger vehicles (16.3 percent). See **Figure 3-6.**

FIGURE 3-6. Angle/Sideswipe LCM crashes Roadway Surface Condition



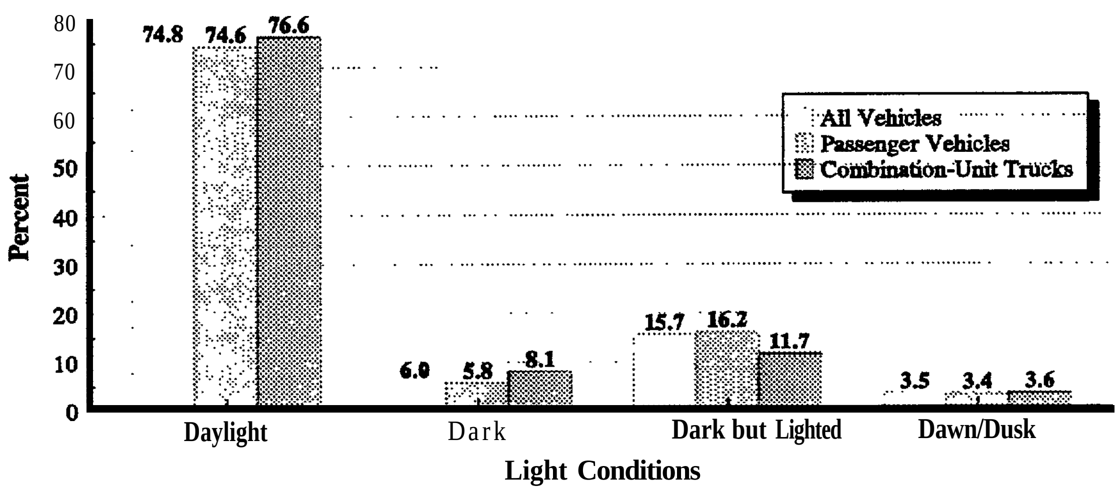
- **Speed Limit**

Target crashes occurred on roadways with a wide range of speed limits. About 71.5 percent of the combination-unit truck target crashes occurred on 55mph or 65mph highways, versus 23.4 percent passenger vehicle crashes.

- **Light Conditions**

Approximately 90.5 percent of the target crashes occurred during daylight or on dark but lighted roadways. See Figure 3-7 for a percentage breakdown for different vehicle types.

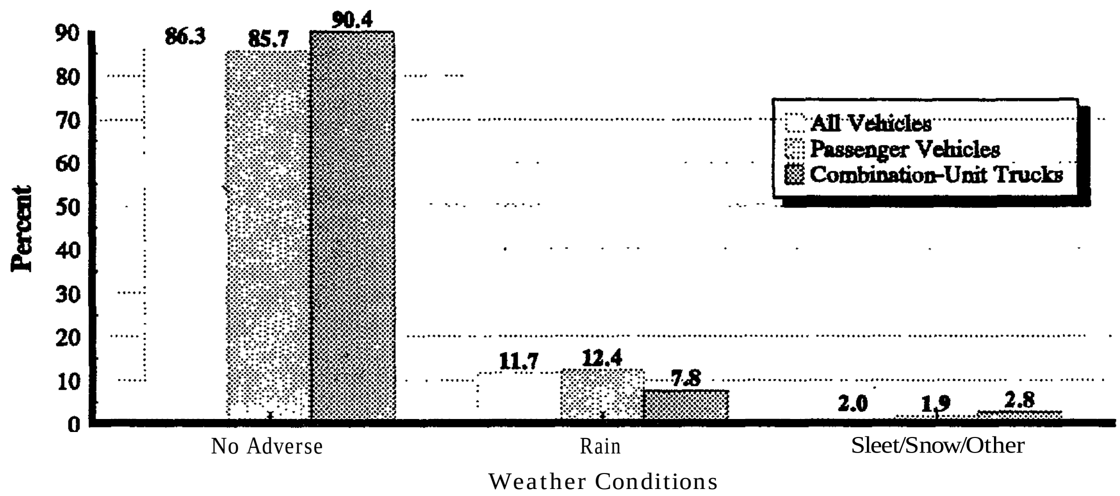
FIGURE 3-7. Angle/Sideswipe LCM Crashes by Light Conditions



- **Weather**

Figure 3-8 shows that more than 85.0 percent of angle/sideswipe LCM crashes occurred under no adverse weather conditions, 11.7 percent occurred on raining weather and 2.0 percent on other (e.g. sleet, snow, etc.) weather conditions. There is litter difference between passenger vehicles and combination-unit trucks.

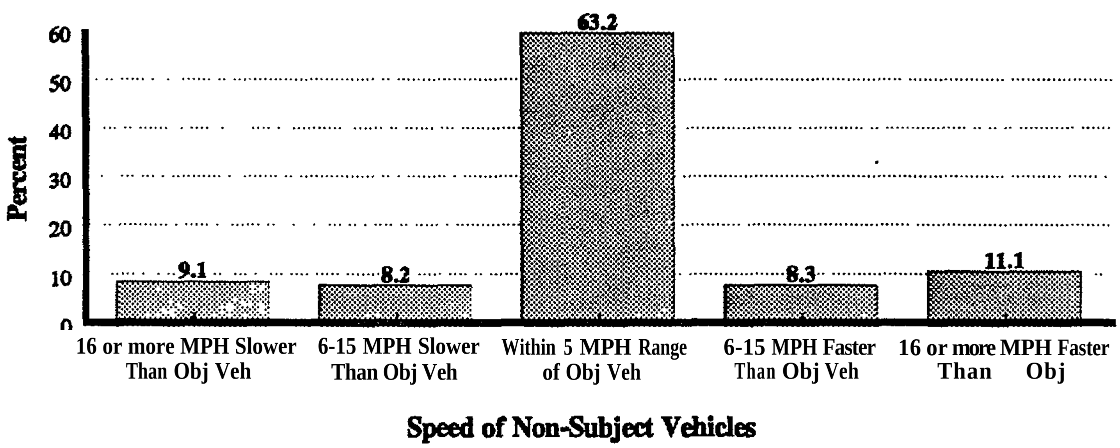
FIGURE 3-8. Angle/Sideswipe LCM Crashes by Weather Conditions



- Pre-Crash Travel Speed

Unknown rates for pre-crash speed were high -- nearly 70 percent. Figure 3-9 illustrates the pre-crash speed of non-subject vehicles compared to that of subject vehicles for those cases in which pre-crash speeds were known. It indicates that most non-subject vehicles traveled at speeds within 5 mph of subject vehicles.

FIGURE 3-9. Angle/Sideswipe LCM Crashes by Pre-Crash Speeds of Non-Subject Vehicles



Not surprisingly, for lower subject vehicle speeds (i.e. O-20 mph), a larger percentage of non-subject vehicles are going faster. For higher subject vehicle speeds (i.e., 51-80 mph), a larger percentage of non-subject vehicles are going slower. **See Table 3-1.**

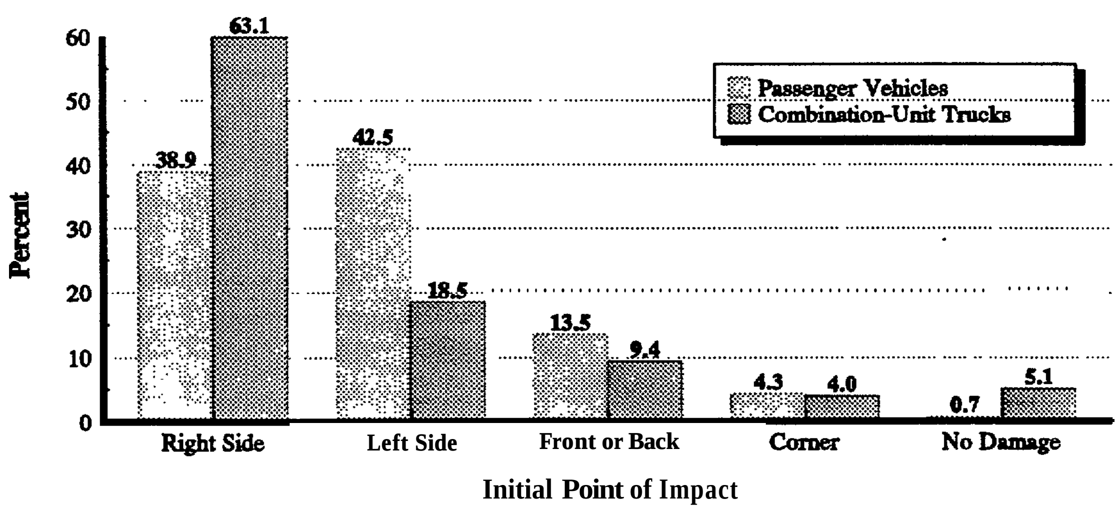
TABLE 3 -l. Vehicle Speed

Speed Of Subject Vehicle	Speed of Other Vehicle to Subject Vehicle					
	16 or more mph slower	6-15 mph slower	Within 5 mph range	6-15 mph faster	16 or more mph faster	Total
0-20	2.1%	4.7%	505%	10.3%	32.3%	99.9%
21-50	13.0%	8.6%	67.3%	8.4%	2.6%	99.9%
51-80	10.3%	12.3%	72.4%	4.9%	0.0%	99.9%
Total	9.1%	8.2%	63.2%	8.3%	11.1%	99.9%

Point of Impact

Passenger vehicles were slightly more likely to have their initial impacts on the left side than on the right side. In contrast, combination-unit trucks as subject vehicles tended strongly to be damaged more on the right side than on the left side. The statistics shown in **Figure 3-10** imply that trucks are more likely to be involved in left-to-right LCM crashes, whereas cars are about equally likely to be involved in left-to-right and right-to-left maneuver crashes.

FIGURE 3-10. Angle/Sideswipe LCM Crashes by Initial Point of Impact



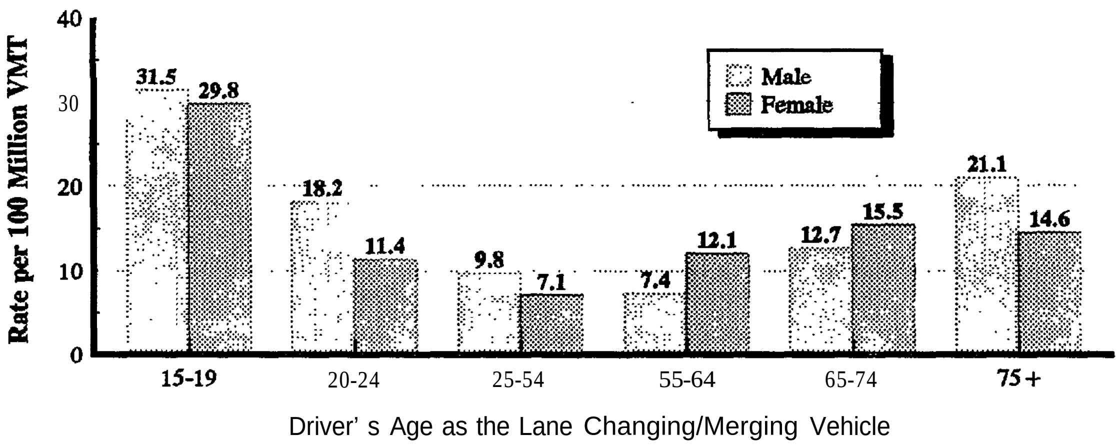
- **Obstruction of Driver Vision**

Obscuring of driver vision was noted very rarely (about 1 percent of involvements of subject vehicles with hit & run vehicles excluded). There were little difference between passenger vehicles and medium/heavy trucks (combination-unit and single-unit trucks).

- **Crash Involvement Rate by Driver Age and Sex**

Figure 3-11 shows graphically'the angle/sideswipe LCM crash involvement rates by age group for men and women as the angle/sideswipe LCM driver. The age distribution shows the familiar "U-shaped" distribution, with teenaged drivers having the highest rate of involvement. Overall, males had a slightly higher involvement rate (11.5 per 100 million vehicle miles traveled) than females (9.6) as the subject vehicle driver.

FIGURE 3-11. Angle/Sideswipe Lane Change/Merge Crash Involvement Rate by Drivers' Age and Sex



3.2 Longitudinal Impact Location Analysis

For the detailed analysis of longitudinal impact location, 1982-1984 NASS Continuous Sampling Subsystems (NASS CSS) were accessed. Although CSS has a larger sampling error than GES, it is a good information source regarding damage location. Such detailed damage location data is not contained in Police Accident Reports and thus is not captured by GES. The angle/sideswipe LCM crashes were defined as follows in 1982-1984 NASS CSS:

Lane change-to-left crashes/impact to left side of lane changing vehicle

Crashes involving a vehicle with criteria:

- Last Action Prior to Avoidance Maneuver (PRIORLAT) = 08 (Changing Lanes to the Left)
- Initial Impact (VEHSEQl, VEHSEQ2, VEHSEQ3 or VEHSEQ4) = 1
- Lane-changing vehicle Deformation Location of Initial Impact (one of GADl, GAD2, GAD3, or GAD4, is corresponding to VEHSEQl..VEHSEQ4) = 'L'
- Type of Damage Distribution of Initial Impact (TDDl, TDD2, TDD3 or TDD4) = 'S'

Lane change-to-right crashes/impact to right side of lane changing vehicle

Crashes involving a vehicle with criteria:

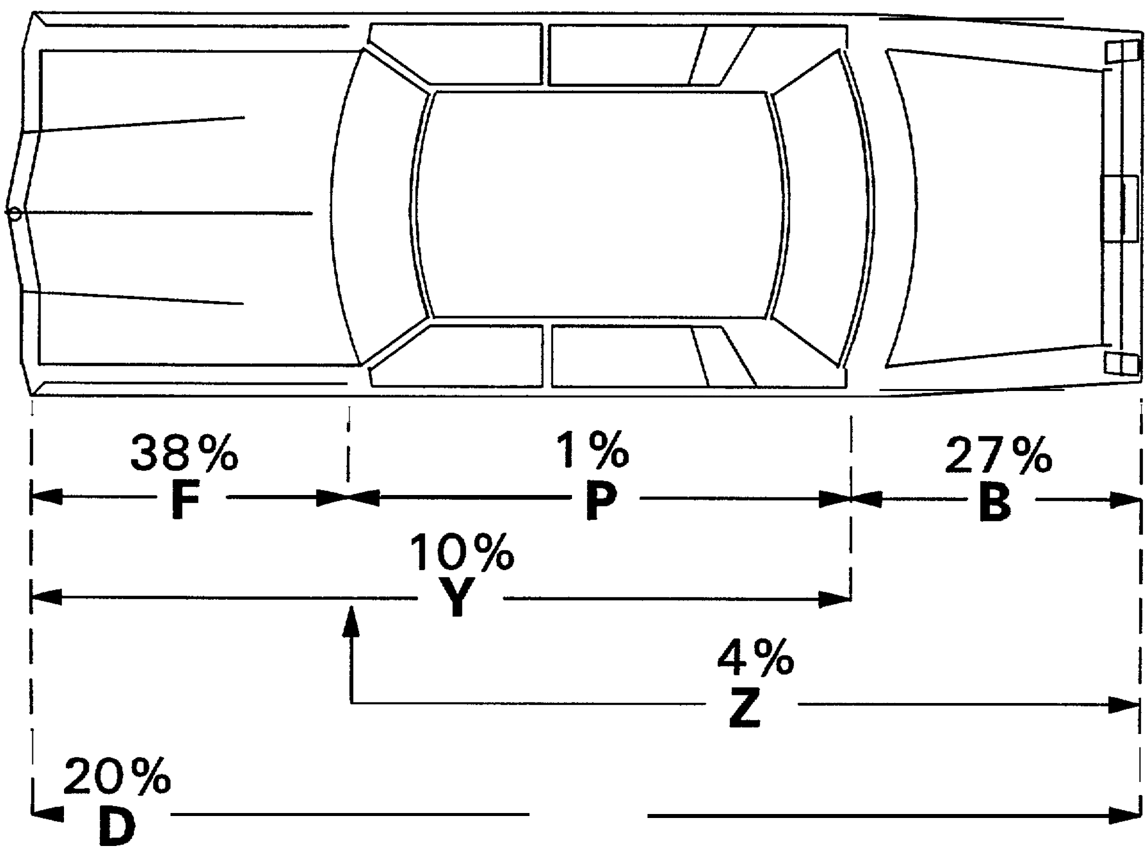
- Last Action Prior to Avoidance Maneuver (PRIORLAT) = 09 (Changing Lanes to the Right)
- Initial Impact (VEHSEQl, VEHSEQ2, VEHSEQ3 or VEHSEQ4) = 1
- Lane-changing vehicle Deformation Location of Initial Impact (one of GADl, GAD2, GAD3, or GAD4, is corresponding to VEHSEQl . . VEHSEQ4) = 1
- Type of Damage Distribution of Initial Impact (TDDl, TDD2, TDD3 or TDD4) = 'S'

Analysis of longitudinal location of impact was performed for passenger vehicles (BODYTYPE = 01-13 or 40-46). Altogether, there were 69 non-weighted cases involving passenger vehicles. Thirty-five of 69 cases were merge-to-left with impacts on the left side, 34 cases were vehicle merge-to-right with impacts on the right side.

There are three basic damage zones along the longitudinal direction: "F" for front, "P" for middle area and "B" for back (For passenger cars, "P" extends longitudinally from the windshield to the rear of rearmost seat). Also, there are three combination zones: "Z" - if the damage extends into zones P and B, "Y" - if the damage extends into zones F and P, "D" - if damage extends across F, P and B. Figure 3-12 and Figure 3-13 depict the longitudinal damage distribution of lane changing to left and right passenger vehicles respectively,

FIGURE 3-12

LONGITUDINAL LOCATION OF DAMAGE
Lane Change-To-Left Crashes
Impact to Left Side of Lane-Changing Vehicle
(NASS CSS, 1982-I 984)



Rearward-Most-Extent of Damage:

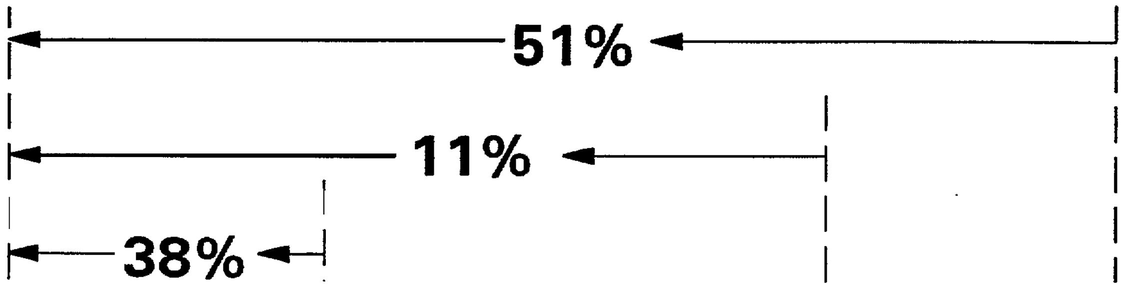
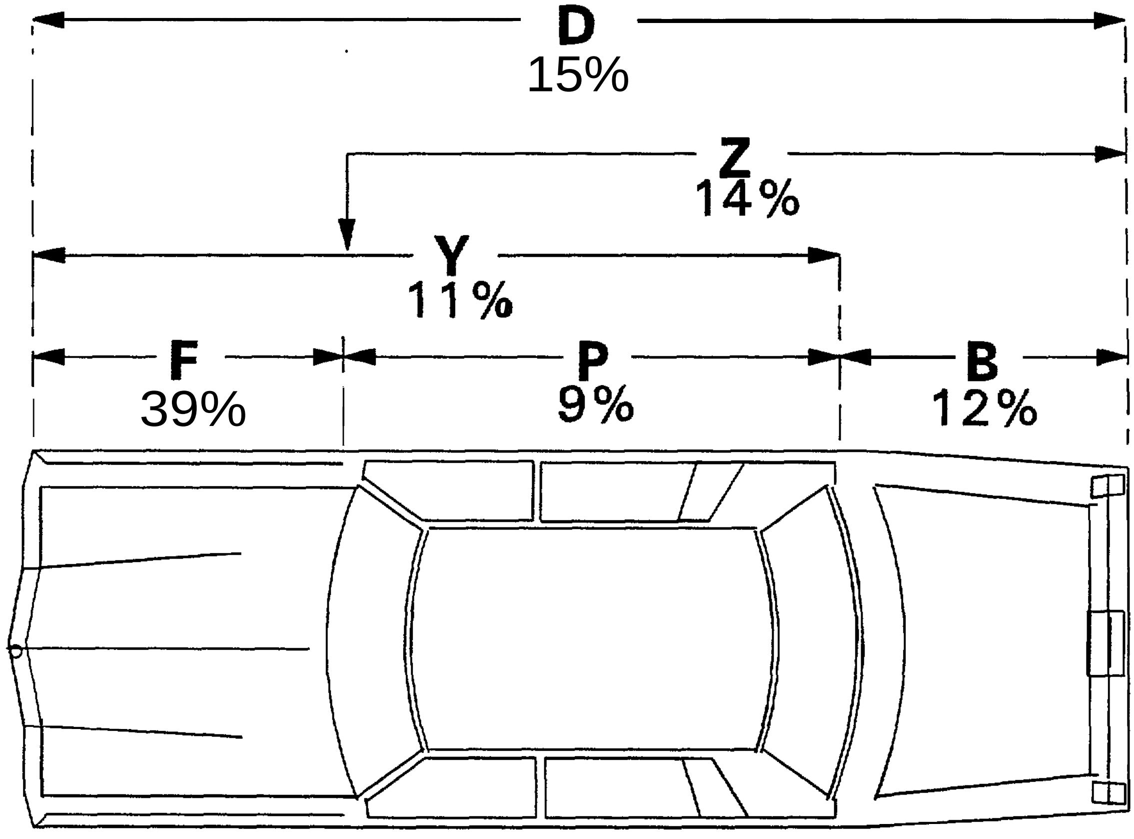


FIGURE 3-13

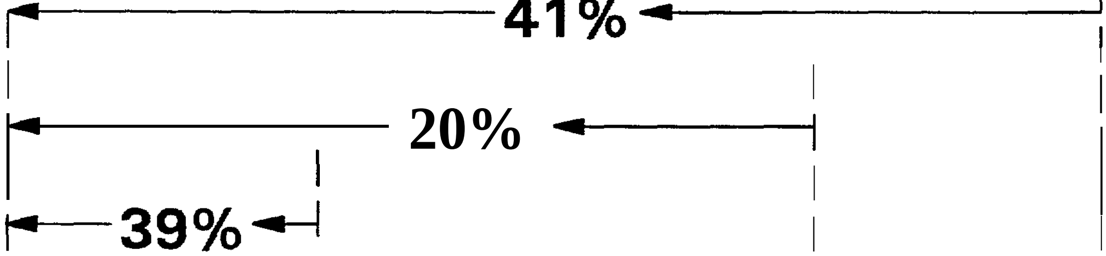
LONGITUDINAL LOCATION OF DAMAGE

Lane Change-To-Right Crashes
Impact to Right Side of Lane-Changing Vehicle

(NASS CSS, 1982-l 984)



Rearward-Most-Extent of Damage:



4, TRI-LEVEL STATISTICS ON CRASH CAUSES

Indiana Tri-Level study (Treat et al, 1979 a; see section A.15 of Appendix A of this report) findings on the causal factors associated with 19 lane change/merge (LCM) crashes. 14 of the 19 cases are "change trafficway, turn across path - initial same direction" crashes (CARDfile Accident Type 413, 415 and 417), 4 of those are "straight turning, resulting same direction" (CARDFILE 505 and 507), and 1 of 19 cases is "sideswipe, same direction" (CARDfile Accident Types 221, 223, 225, 227, 231 and 233).

In the Tri-Level study, multiple crash causes were often indicated. At the broadest level of classification, one finds that human factors were cited as certain or probable causes in all the 19 cases. Recognition errors are most frequently cited (17 cases; 89 percent). No vehicular factors are indicated for LCM crashes.

The crash causes at more detail levels for the LCM crashes provided below.

Lane Change/Merge Crashes (19 cases):

- Human causes (19 cases, 100%)

  Direct human causes (19 cases, 100%)

  Recognition errors (17 cases, 89%)
  Recognition delays -- reasons identified (16 cases, 84%)
  Inattention (1 cases; 5%)
  External distraction (1 case; 5%)
  Driver-selected outside activity (1 cases, 5%)

  Improper lookout (15 cases; 79%)
  Entering traffic from street, alley (4 cases, 21%)
  Prior to changing lanes, passing (7 cases, 37%)
  Improper lookout -- other (7 cases, 37%)

  Decision errors (14 cases, 74%)
  False assumption (4 cases, 21%)
  Improper maneuver (11 cases, 58%)
  Turned from wrong lane (8 cases, 42%)
  Drove in wrong direction of travel (1 case, 5%)
  Passed at improper location (2 cases, 10%)

  Improper driving technique (2 cases, 10%)

Driving technique -- inadequately defensive (4 cases, 21%)
Positioned car differently (1 case, 5%)
Adjusted car's speed (2 case, 10%)
Driving technique -- inadequately defensive other (1 case, 5%)

Excessive speed (1 case, 5%)
For road design -- regardless traffic (1 case, 5%)

Tailgating (1 case, 5%)
Inadequate signal (4 cases, 21%)
Failure to signal for turn (3 cases, 16%)
Failure to use horn to warn (1 case, 5%)

Improper evasive action (1 case, 5%)
Locked brakes, couldn't steer - tired (1 case, 5%)

Performance errors (1 case, 5%)
Inadequate directional control (1 case, 5%)

Indirect human causes (1 case, 5%)
Mental or emotional (1 case, 5%)
Pressure from other drivers (1 case, 5%)

- Environmental causes (slick roads, view obstructions) (2 case, 10%).

These data are consistent with a principal causal factor of recognition failure ("did not see other vehicle") for LCM crashes. An LCM crash causal factor assessment by Chovan et al (1993) corroborates this finding.

APPENDIX A: PROBLEM SIZE AND DESCRIPTIVE STATISTICS

Target crash problem size assessments and descriptive statistics are based on counts and estimates accessed from available crash datafiles. For target crash problem size assessment, raw statistics are typically manipulated statistically to provide more usable and comprehensive problem size statistics. This appendix describes the datafiles accessed and the statistical measures that are derived from those estimates.

A.1 Crash Datafiles and Other Information Sources Accessed

The following data sources have been used to estimate lane change/merge and "all crashes" problem size and descriptive statistics:

A.1.1 NHTSA General Estimates System (GES)

GES, one of the two major subsystems of the current National Accident Sampling System (NASS), is a survey of approximately 43,000 Police Accident Reports (PARs) from 60 geographic sites (jurisdictions) in the U.S. The PAR is the only source of data for GES. A data coder reviews the PAR and then codes the GES variables. GES is a comprehensive crash data file, addressing all vehicle and crash types and crash severities. Since the GES sample size is moderate (rather than large like the Crash Avoidance Research Data file; CARDfile), its reliability is greatest when relatively large crash problems are examined. For low-frequency crashes, the reliability of GES data may be questionable.

Estimates presented in this report have been rounded to nearest 1,000. As a result of rounding, some table entries may not sum to the posted totals. In addition, percentage estimates and the derived statistics in the tables were calculated before numbers were rounded.

Appendix C of this report is excerpted from a publication entitled 'Technical Note for 1989, 1990, 1991 National Accident Sampling System General Estimates System" (DOT HS 807 796). Appendix C provides tables for estimating the standard errors of GES estimates. Although point estimates are provided in this report, it is critical to realize that each GES estimate (whether of crashes, vehicles, or injuries) has an associated sampling error. The tables in Appendix C can be used to derive, through interpolation, the standard error of each GES estimate (or the standard error of statistics derived from GES estimates). Estimation reliability improves with increasing crash/vehicle/injury numbers; i.e., standard errors are smaller, relative to the estimate, for larger estimates.

AS.2 NHTSA Fatal Accident Reporting System (FARS)

FARS is a census of data on all fatal crashes in the U.S. FARS contains descriptions of each fatal crash using 90 coded variables characterizing the accident, vehicle, and people involved. The PAR is the primary source of information on each fatal crash, although supplementary information is also used, such as medical reports on blood alcohol content. FARS statistics are crash/vehicle/fatality counts, not estimates. There is no associated standard error.

A.1.3 NHTSA NASS Continuous Sampling Subsystem (CSS)

The NASS Continuous Sampling Subsystem (CSS) was a nationwide accident data collection program sponsored by NHTSA. During the 1982-86 timeframe, NASS CSS data were collected from 50 sites selected to be representative of the continental U.S. NASS crash investigations were regarded as "Level II" investigations; i.e., they were far more in-depth than police accident reports (Level I), but were not comprehensive in-depth investigations (Level III). NASS investigations emphasized crashworthiness and occupant protection concerns, but also collected useful information relating to crash causation. Approximately 12,000 cases were investigated each year. The sampling error problem discussed above for GES is even greater for NASS statistics. Therefore, the CSS is generally not a good source of statistics relating to problem size of low-frequency crash types. NASS CSS data are not cited in this report.

k1.4 NHTSA NASS Crashworthiness Data System (CDS)

The NASS CDS is a nationally-representative sample of police-reported crashes occurring throughout the U.S. involving at least one towed passenger car, light truck, van or utility vehicle. CDS was implemented in 1988 as a follow-on to the NASS CSS (see above). CDS investigates about 5,000 crashes annually, proving detailed information on injuries and injury mechanisms. Consistent with its specific emphasis on crashworthiness, CDS provides more detailed information than CSS on vehicle damage and associated occupant injuries, but less information on accident circumstances (e.g., environmental conditions, collision scenarios). (Note, however, that CDS has added new variables on pre-crash events beginning with the 1992 data collection year).

CDS data are not cited in this report, but have been used as part of the related lane change/merge "problem definition/countermeasure technology assessment" program described in Chapter 1.

A.1.5 Tri-Level Study of the Causes of Traffic Accidents

The Indiana Tri-Level Study (Treat et al, 1979a), was an in-depth study of crash causes conducted in the late 1970s by Indiana University. The term "Tri-Level" referred to the collection of three qualitatively-different types of data: mass data (e.g., driver license data including past violations), on-scene crash data (e.g., driver interviews, photography of skidmarks and vehicle final rest positions), and follow-up reconstructions, which included a consideration of human, vehicle, and environmental factors contributing to the crash. Although the study sample size was small (i.e., 420 in-depth cases) and geographically lirnited (i.e., rural Indiana), it employed an elaborate and insightful taxonomy of crash causal factors. The recent addition of CARDfile accident type codes to the Indiana sample by NHTSA has made it possible to use the Tri-Level findings on causal factors in conjunction with CARDfile and other databases. In this report, the Tri-Level data will not be used to quantify problem sizes, but will be used to provide insights on causes of crash types. Applicable statistics from the Tri-Level Study are cited in the narrative text of this report; detailed statistical summaries from the study have been prepared as separate documents.

A.1.6 FHWA Statistics on Vehicle Registrations and Vehicle Miles Traveled

Statistics on vehicle registrations and vehicle miles traveled (VMT) were obtained from the Federal Highway Administration (FHWA) publication Highway Statistics 1991 (FHWA-PL-92-025). Table VM-1 (Page 193) of this publication provides summary statistics on registrations and VMT by vehicle type. Registration statistics are used to calculate annual likelihoods of involvement and probabilities of involvement over vehicle life. VMT statistics are used to calculate rates of crash involvement.

A.2 Statistical Measures of Problem Size

Target crash problem size assessments are intended to estimate the total number of crashes, fatalities, injuries, and delay hours resulting from target crashes. This includes all fatalities/injuries sustained in all vehicles (and non-vehicles) involved in the target crash. For example, for the "lane changing/merging combination-unit truck", the fatality/injury counts include both the occupants of the truck and any other involved vehicles and non-motorists (e.g., pedestrians).

For most target crash types (including lane change/merge crashes), problem size estimates are provided for three vehicle type categories: all vehicle types combined, passenger vehicles (automobiles, light trucks, vans), and combination-unit trucks. in addition, for lane change/merge crash problem size statistics are provided for medium-heavy single-unit trucks. The following statistical measures of problem size are derived and reported in the problem size assessments:

1. Annual Number of Police-Reported (PR) Target Crashes — ***Accessed from datafile (GES, NASS, etc.)***

- Injury Crashes — ***Includes fatal crashes***
- Property-Damage Only (PDO) — ***Includes crashes of unknown severity***

Explanation: The annual number of PR crashes is estimated from one of several crash datafiles. The selection of which datafile to use depends primarily on the "match" between coded data element definitions and the target crash type under consideration. For lane change/merge crashes, the estimate is from the 1991 GES. As noted above, GES estimates have an associated standard error of estimate. These are provided for major statistical estimates (e.g., total number of target crashes), and the reader 'may determine the approximate standard error for any GES estimate contained in this report by using the tables in Appendix C.

2. Annual Number of Fatalities — ***Accessed from datafile (generally FARS)***

Explanation: FARS statistics are preferred, since FARS provides a count of fatalities, as opposed to an estimate. FARS statistics are used for the lane change/merge analysis. When FARS statistics are not available (i.e., FARS does not code the variable of interest), GES, CARDfile, state, or other data are used to generate a national estimate of the number of fatalities. The fatalities estimate includes fatalities occurring in all vehicles, pedestrians, and pedalcyclists involved in target crashes.

3. Annual Number of (Non-Fatal) Injuries in PR Crashes — ***Accessed from datafile (GES, CARDfile, etc.); Sum = A + B + C+D or MAIS 5+4+3+2+1***

- KABCO Scheme: — ***Severity scheme used in most datafiles***
  - Incapacitating Injury (A)
  - Nonincapacitating Injury (B)
  - Possible Injury (C); includes "injured, unknown severity" (D)
  - No Injury (0); includes other unknowns

- **MAIS** — ***Severity scheme used in NASS*** css a?ld CDS
  - Critical (MAIS 5)
  - Severe (MAIS 4)
  - Serious (MAIS 3)
  - Moderate (MAIS 2)
  - Minor (MAIS 1)
  - No Injury (MAIS 0); includes unknowns

Explanation: For lane change/merge crashes, injuries are assessed based on GES data. Totals include all non-fatal injuries (i.e., A+ B + C + D injuries in GES) resulting from target crashes (all involved vehicles/non-vehicles). As noted previously, GES estimates have an associated standard error of estimate. These are provided for major statistical estimates (e.g., total number of injuries), and the reader may determine the approximate standard error for any GES estimate contained in this report by using the tables in Appendix C.

4. Annual Total Fatal Crash Equivalents (FCEs)

Total Fatal Crash Equivalents (per GES crash severity), whereby fatal crashes are assigned a value of 1.0, and non-fatal crashes are assigned relative severity values between 0 and I.

Explanation: "Harm" is an abstract concept referring to the total societal loss (e.g., deaths, injuries, property damage) associated with crashes. Here, the statistic "fatal crash equivalent" (FCE), which is similar to Harm, is used to capture total societal loss. FCE is derived from target crash severities. Crash severity is measured in terms of the most severe police-reported crash injury (the widely-used "KABCO" scheme). The KABCO value is then converted to an FCE value so that crashes of different severities can be measured and assessed on a single ratio scale. Using the FCE scale, two different crash types (e.g., a high severity/low frequency type with a low severity/high frequency type) can be compared directly in terms of their total effect on society.

Table A-l (based on Miller, 1991) shows how the "fatal crash equivalent" scale is derived from police-reported crash severity ('KABCO"). Note that the use of FCEs cancels out the dollar values so that only relative values assigned to crashes of various severities are factored into the severity reduction calculations. Note also the sharply increasing "Willingness to Pay" value of crashes with increasing KABCO severity, and thus the sharply increasing FCE value. For example, in the analysis, one "A" crash will carry the same weight as approximately nine "c" crashes. Thus, the more severe crashes will tend to "drive" the cumulative "fatal crash equivalents" values.

For consistency, unless otherwise noted, the coded GES non-fatal crash severity (i.e. A-incapacitating, B-Non-incapacitating, C-Possible injury, and O-No injury) and FARS fatal crash (K-Fatality) are used to determine total FCEs for all crashes and for all crash types. Final value of total FCEs is rounded to nearest unit.

TABLE A-l: CONVERSION TABLE FOR DERIVING "FATAL CRASH EQUIVALENTS" FROM POLICE-REPORTED CRASH SEVERITY (from Miller, 1991)

"FATAL EQUIVALENTS" CRASH SEVERITY SCALE		
Crash Severity (Most severely-injured occupant, KABCO)	**Comprehensive $ Value Per Crash (1988 Dollars, 4% Discount Rate)**	**Fatal Crash Equivalent ("FCE")**
Fatality (K,4)	$2,722,548	1.0000
Incapacitating (A,3)	$228,568	0.0840
Non-incapacitating (B,2)	$48,333	0.0178
Possible (C, 1)	$25,228	0.0093
No Injury (0,0)	$4,489	0.0016
Unreported	$4,144	0.0015

5. Percentage of All Police-Reported (PR) Crashes	***Percentage of the total number of crashes (for subject vehicle type) represented by this crash type***
Percentage of All Crash FCEs	***Percentage of the total crash fatal crash equivalents for subject vehicle type represented by this crash type***
Percentage of All Crash Fatalities	***Percentage of all crash fatalities (involving subject vehicle type) represented by this crash type***

Explanation Relates this crash type to the overall traffic crash problem for the vehicle type in question. Comparison of the three percentages provides one measure of crash severity relative to crashes in general. For example, lane change/merge crashes account for a high percentage of PR crashes, a moderate percentage of FCE, and a relatively low percentage of fatalities.

Crashes are assigned FCE values with regard to severity (most severely injured person) only and regardless of the number of vehicles involved, crash type, or vehicle type. Thus the measure may be somewhat unreliable for "exceptional' crash types such as single vehicle crashes and combination-unit truck crashes.

6. Involvement Rate Per 100 Million Vehicle Miles Traveled	***Calculated from target PR crashes*** and *VMT*

Explanation: Involvement rates per 100 million vehicle miles traveled are calculated from annual target crash estimates and annual VMT estimates **(see Table A-2** below). When the problem is defined for a particular vehicle role (e.g., lane changing/merging vehicle in a lane change/merge crash), the involvement rate is based on involvements in that role only. It may then be termed the subject vehicle; i.e., the crash-involved vehicle that, if equipped with the countermeasure, could potentially have avoided the crash. Other involvement rates provided do not specify a vehicle role; these include involvements in all crashes and involvements in lane change/merge crashes regardless of role. For each involvement rate provided, this report will specify whether the rate is based on "subject vehicle involvements only" or "all involvements." Note that the passenger vehicle mileage data in Table A-2 includes both passenger cars and 2-axle, 4-tire single-unit trucks (i.e., pickup and vans). The single-unit truck data shown does nor include 2-axle, 4-tire trucks and thus corresponds to the "Other Single-Unit Trucks" column of Table *VM-1* of *Highway Statistics.*

TABLE A-2: 1990 AND 1991 VEHICLE MILES TRAVELED (IN MILLIONS) FOR VARIOUS VEHICLE CATEGORIES
(Source: *Highway* Statistics, 1991, FHWA, Table VM-1)

ANNUAL VEHICLE MILES TRAVELED (VMT, in millions)		
Vehicle Category:	**1990**	**1991**
All Vehicle Types'	2,147,501	2,172,214
Passenger Vehicles	**1,982,197**	2,006,553
Combination-Unit Trucks	96,482	96,949
Single-Unit Trucks	53,522	53,791

Average annual miles traveled per vehicle in 1991 were as follows for these four vehicle type categories:

- All vehicle types: 11,281 miles
- Passenger vehicles: 11,032 miles
- Combination-unit trucks: 60,429 miles
- Single-unit trucks: 12,656 miles.

7. Annual "Likelihood" of Involvement (Annual Involvements Per 1,000 Vehicles) — ***Calculated from target PR crashes and vehicle registrations***

Explanation: This statistic provides a useful annual perspective on "likelihood" of involvement in target crashes (as the subject vehicle). It is determined by the following formula:

$$\text{Annual Involvements Per 1,000 Vehicles} = \frac{\text{1,000 X Target Crashes}}{\text{\# Registered Vehicles}}$$

Like involvement rate per 100 million VMT, this statistic may be calculated based on all involvements (e.g., all crashes, all lane change/merge crashes) or based upon a particular vehicle role in the crash (e.g., lane changing/merging vehicle in lane change/merge crash). Note that the passenger vehicle registration data in Table A-3 includes both passenger cars ***and 2-axle, 4-tire*** single-unit trucks (i.e., pickup and vans). The single-unit truck data shown does not include Z-axle, Ctire trucks and thus corresponds to the "Other Single-Unit Trucks" column of Table VM-1 of Highway Statistics.

TABLE A-3: 1990 AND 1991 VEHICLE REGISTRATIONS FOR VARIOUS VEHICLE CATEGORIES (Source: *Highway* Statistics, 1991, FHWA, Table VM-1)

VEHICLE REGISTRATIONS		
Vehicle Category:	**1990**	**1991**
All Vehicle Types	**192,914,924**	**192,548,972**
Passenger Vehicles	**182,201,372**	181,885,983
Combination-Unit Trucks	**1,607,183**	**1,604,335**
Single-Unit Trucks	**4,219,920**	**4,250,338**

8. Expected Number of Involvements During Vehicle Life

Calculated from target PR crashes, vehicle registrations, and average vehicle life

Explanation: The expected number of crash subtype involvements during the vehicle life is determined by the following formula:

Expected Number = $\frac{\text{Annual Involvements in Target Crashes X Average Vehicle Life}}{\text{\# Registered Vehicles}}$

Like the previous two statistics, this statistic may be calculated based on all involvements (e.g., all crashes, all lane change/merge crashes) or based upon a particular vehicle role in the crash (e.g., lane changing/merging vehicle in lane change/merge crash). For specific crash types (and especially for specific vehicle roles in specific crash types), this value is typically low; i.e., less than 0.2. For such low values, the statistic can be treated as an approximate ***probability*** estimate **to** answer the question, "What is the probability that a vehicle will "need" the subject countermeasure during its life?" This statistic can also be used to derive per-vehicle-produced target crash "value" (average crash value times expected number during vehicle life).

Statistical constants used to make these calculations include the following:

- Vehicle registrations: same values as used above (Item 7)
- Vehicle life, all vehicle types combined: 13.13 years. This value was derived **from** Miaou (1990) based on a weighted average of the average operational lives of passenger cars (11.77 years) and "all trucks" (15.84 years). The relative weights for calculating the weighted mean were based on 5-year averages (1987-91) of U.S. retail sales for these two vehicle categories (MVMA, 1992).
- Vehicle life, passenger vehicles: 13.01 years. This value was derived from Miaou (1990) based on a weighted average of the average operational lives of passenger cars (11.77 years) and light trucks (16.05 years). The relative weights for calculating the weighted mean were based on 5-year averages (1987-91) of U.S. retail vehicle sales for these two vehicle categories (MVMA, 1992).
- Vehicle life, medium/heavy trucks (both combination-unit and single-unit): 14.70 years (Miacu, 1990). Miaou's data did not separate combination-unit and single-unit trucks. A possible future refinement of this analysis would employ separate life values for these two vehicle types.

Note also that Miaou's estimated vehicle life values are based on analyses of the registration period from 1978 to 1988 (or 1989). Miaou's data show a trend toward longer vehicle lives for more recent time periods (e.g., 1978-88 versus 1966-73). If this trend continues, vehicles purchased now and in the coming decade will have somewhat longer operational lives than the values used here. A trend toward longer vehicle life is corroborated by R. L. Polk and Company data, cited in Davis and Morris (1992), showing that the average age of both automobiles and trucks in use has increased steadily over the past 20 years.

9. Estimated Annual Number of Non-Police-Reported (NPR) Target Crashes	***Estimated per algorithm described below***
• Injury Crashes	***Estimated to be 11.8% of NPR target crashes***
• Property-Damage Only (PDO)	***Estimated to be 88.2% of NPR target crashes***

Explanation: The estimate of Non-Police Reported (NPR) crashes is based on the known number of PR PDO crashes and the estimated total number of NPR crashes nationally. Specifically, the following equation is used to estimate target NPR crashes:

$$\text{Target NPR Crashes} = \frac{\text{Target PR PDO Crashes X AU NPR Crashes}}{\text{All PR PDO Crashes}}$$

Statistical constants used to make these calculations include the following:

- All NPR crashes, all vehicle types: 7.77 million (Miller, 1991)
- All NPR crashes, passenger vehicles: 7.66 million (estimated from Miller, 1991, and proportion of passenger vehicle involvements in PR PDO crashes).
- All NPR crashes, combination-unit trucks: 0.29 million (estimated from Miller, 1991, and proportion of combination-unit truck involvements in PR PDO crashes).
- All NPR crashes, single-unit trucks: 0.19 million (estimated from Miller, 1991, and proportion of single-unit truck involvements in PR PDO crashes).
- Percentage of NPR crashes with injuries: 11.8 percent (Greenblatt et al, 1981; same value used for all vehicle type categories).

NPR crash problem size estimations resulting from the above algorithm should not be accepted uncritically. The algorithm assumes proportionality between NPR crashes and PR PDO crashes, which are generally more severe than NPR crashes. The algorithm likely overestimates NPR crashes for crash types that are often serious and thus not likely to go unreported. Examples include head-on crashes and rollovers. On the other hand, the algorithm likely underestimates NPR crashes for crash types that are usually minor in severity and thus less likely to be reported. Examples include rear-end crashes and backing crashes. As this program progresses, it may be possible to develop a more sophisticated NPR crash estimation algorithm or to incorporate findings from other sources (e.g., insurance claim data) to better estimate NPR crashes.

Miller (1991) estimated the average comprehensive value of unreported crashes to be $4,144, corresponding to a fatal crash equivalent ("FCE") value of 0.0015. However, the FCE associated with NPR crashes is not incorporated into the FCE estimates of this report.

10. Estimated Total Annual Target Crashes	***Total target crashes (UDH + Non-UDH)***
• Urban-Divided Highway (UDH)	***Total PR + NPR***
- PR	***Accessed and imputed from datafile***
- NPR	***Estimated based on PR UDH taget crashes***
• Non-Urban Divided Highway	***Total PR + NPR***
- PR	***Accessed and imputed from datafile***
- NPR	***Estimated based on PR Non-UDH target crashes***

Explanation: The UDH/non-UDH breakout is used to estimate delay caused by target crashes (see item #11 below). Target UDH NPR values are estimated from PR values as follows:

$$\text{Target UDH NPR Crashes} = \frac{\text{Target UDH PR Crashes X Target NPR Crashes}}{\text{Target PR Crashes}}$$

GES classifies its geographic Primary Sampling Units (PSUs) using a "Percent Rural" scale based on 1980 U.S. Census data (not Federal Roadway classification). In GES there are 11 urban/rural categories: Urban, 10 percent Rural, 20 percent Rural, etc. Within a PSU that is part urban and part rural, specific crashes cannot be identified as "urban" or "rural." Disaggregated "urban" and "rural" crash estimates are obtained by an imputation process, as follows:

- 0% of "Urban" crashes are counted as "rural."
- 10% of "10% of Area is Rural" crashes are counted as "rural."
- 20% of "20% of Area is Rural" crashes are counted as "rural."; etc.

This tabulation is performed separately for divided highway and "other" crashes to obtain two estimates for PR crashes: UDH and Non-UDH (i.e., all other). Then the NPR estimates are generated based on the PR estimates.

The PR and NPR breakouts for UDH and Non-UDH crashes are not shown in the crash problem size tables, but are used to estimate vehicle-hours of delay (see below).

The urban vs. rural &aggregation provided by the GES "Percent Rural" variable should be regarded as a rough estimate. Since this variable is determined at the GES PSU level, standard errors for these estimates are based on a sample size of 60 (the number of PSUs) not 43,000 (the number of crashes). The resulting relative errors for these estimates (standards error divided by the estimate) range from 3 to 5 times as great as the relative errors given in Appendix C.

11. Estimated Annual Vehicle-Hours of Crash-Caused Delay	***Estimated from calculations based on UDH vs. Non-UDH breakout***
Percent of All Crash-Caused Delay	***Delay caused by the target crash type as a percentage of all crash-caused delay (estimated here as 450.2 million vehicle hours for 1991).***

Explanation: Crash-caused congestion (delay) is strongly related to crash location and severity. In particular, UDH crashes cause far greater delay per crash than do non-UDH crashes. The following formula is used to estimate total vehicle-hours of delay caused by target crashes:

Total Vehicle-Hours Delay =		300	X	PR UDH Target Crashes
	+	100	X	NPR UDH Target Crashes
	+	5	X	PR Non-UDH Target Crashes
	+	1	X	NPR Non-UDH Target Crashes

The above co-efficients are working estimates based on several studies; e.g., Cambridge Systematics, 1990; Grenzeback et al, 1990. Using the above algorithm, the annual total crash-caused vehicle-hours of delay is estimated to be 450.2 million vehicle-hours for 1991. This value is used to calculate percentages of total crash-caused delay for specific crash types, including those for specific vehicle types. This percentage is intended to provide a sense of how much prevention of this crash type would affect crash-caused roadway congestion.

Crash-caused delay estimations resulting from the above algorithm should not be accepted uncritically. The algorithm assumes that delay is a function of just two factors: crash location and crash severity. Other relevant factors (e.g., involved vehicle types, time of crash, weather conditions) are not incorporated at this time. Moreover, certain crash types are likely to cause greater lane blockage or more lengthy delays due to vehicle extrication efforts than other crashes of the location and severity. For example, head-on crashes are likely to block multiple lanes, and rollover crashes are likely to require extra time for vehicle extrication. As this program progresses, it may be possible to develop a more sophisticated delay estimation algorithm to account for some of these additional factors.

A planned upgrade to the delay estimation algorithm is to use larger average delay values for crashes involving heavy trucks. Currently, this document uses the same delay values for heavy trucks as for other vehicle types. This is known to yield an underestimate of delay caused by truck crashes. Bowman and Hummer (1989) estimated the average delay caused by truck urban freeway crashes to be 914 vehicle-hours. They cited a study by Teal (1988) that estimated the value to be 1,179 vehicle-hours. The median estimate of these two studies is approximately 1,000 hours.. Extending the urban freeway truck-car difference to all vehicle types, a better formula for estimating delay caused by truck crashes might be:

Total Vehicle-Hours Delay =		**1,000**	X	PR UDH Target Crashes
(Heavy Truck Crashes)	+	**300**	X	NPR UDH Target Crashes
	+	15	X	PR Non-UDH Target Crashes
	+	**3**	X	NPR Non-UDH Target Crashes

The above formula is likely to be more accurate for heavy truck crashes. Nevertheless, for simplicity, at present the **same** delay estimation formula is **used for all vehicle type categories.**

A.3 Descriptive Statistics

In addition to problem size assessment statistics, this document provides descriptive statistics relating to crash incidence. These are primarily univariate and bivariate (e.g., vehicle type category by other factor) distributions that characterize the component "subtypes" of the target crash type, conditions under which target crashes occur, and, when possible, statistics providing insights into the primary causes of crashes. The national crash databases described in Section A2 provide very informative data on crash conditions and characteristics, but generally do not specify crash causes with sufficient precision and reliability to permit the identification of appropriate countermeasures or the estimation of countermeasure effectiveness. One important study, the Indiana Tri-Level Study (Treat et al, 1979a; see Section A.1.6), does provide insightful data on crash causes, but is based on only 420 in-depth crashes occurring in rural Indiana. Its representativeness to current national crash problems is thus questionable. However, Indiana Tri-Level statistics are provided when there were a sufficient number of target crash cases to provide meaningful information on crash causes.

A.4 Definitions of Vehicle Types

For most data retrievals (including the lane change/merge retrievals), three vehicle type categories are used:

- All vehicle types (combined)
- Passenger vehicles (automobiles, light trucks, light vans)
- Combination-unit trucks (generally tractor trailers or "bobtail" tractors)

In addition, for selected topics, crash data retrievals are presented for medium/heavy single-unit (straight) trucks.

In GES and FARS, discriminating combination-unit trucks from single-unit trucks (and both from light trucks) requires the use of two different vehicle variables: body type and vehicle trailering. The category "combination-unit truck" is considered to include all tractors (whether pulling a trailer or running bobtail) as well as other medium-heavy trucks that are known to be pulling a trailer. This includes a small number of trucks with single-unit designs that were in fact pulling a trailer at the time of the crash.

GES and FARS use the same element numbering scheme for the "trailering" variable (TRAILER in GES; TOW-VEH in FARS). The scheme is: 0 = no trailer; 1 = 1 trailer; 2 = 2 trailers; 3 = 3 or more trailers; 4 = pulling trailer(s), number unknown; 9 = unknown if pulling trailer.

Moreover, in GES there are a significant number of vehicles with unknown or partially-unknown body types (i.e. 49 = unknown light vehicle type; 69 = unknown truck type; and 99 = unknown body type). In the 1991 GES, for example, these totaled 5.4 percent of vehicles. This means that statistics on individual vehicle body types will underestimate involved vehicles of that type to the extent that vehicles of that type were coded as "Unknown." To correct for this effect, GES problem size statistics for specific body types use the GES variable Hotdeck Imputed Body Type (V51, BDYTYP_H). In the imputed body type variable, vehicles of unknown body type are distributed proportionately across the known body types, thus correcting, as accurately as possible, the problem of the unknown vehicle types.

The vehicle type unknown rate in FARS is low and has no significant impact on crash counts; thus, there are no "imputed" vehicle types in FARS.

Below is a summary of the definitions used and relevant caveats. For each GES statistic, the Hotdeck Imputed Body Type (V5I, BDYTYP H) variable is used for problem size assessment and the descriptive statistics.

<u>GES Passenger Vehicle (Car/Lt.Trk/Van)</u>:

01 $\le$ Body Type $\le$ 49

<u>GES Combination-Unit Truck</u>:

Body Type = 60 (single-unit straight truck) & 1 $\le$ TRAILER $\le$ 4
Body Type = 65 (truck-tractor, cab only or any number of trailers)
Body Type = 68 (unknown medium/heavy truck) & 1 $\le$ TRAILER $\le$ 4
Body Type = 69 (unknown truck type) & 1 $\le$ TRAILER $\le$ 4

<u>GES Single-Unit Truck</u>:

Body Type = 60 (single-unit straight truck) & TRAILER = 0 or 9 (unknown)
Body Type = 68 (unknown medium/heavy truck) & TRAILER = 0 or 9 (unknown)

<u>FARS Passenger Vehicle (Car/Lt.Trk/Van)</u>:

01 $\le$ Body Type $\le$ 49

<u>FARS Combination-Unit Truck</u>:

Body Type = 61 (single-unit straight truck, GVWR 10,000-19,500) & 1 $\le$ TOW VEH $\le$ 4
Body Type = 62 (single-unit straight truck, GVWR 19,500-26,000) & 1 $\le$ TOW_VEH $\le$ 4
Body Type = 63 (single-unit straight truck, GVWR over 26,000) & 1 $\le$ TOW_VEH $\le$ 4
Body Type = 64 (single-unit straight truck, GVWR unknown) & 1 $\le$ TOW-VEH $\le$ 4
Body Type = 66 (truck-tractor; cab only or any number of trailers)
Body Type = 71 (unknown medium truck, GVWR 10,000-26,000) & 1 $\le$ TOW-VEH $\le$ 4
Body Type = 72 (unknown heavy truck, GVWR over 26,000) & TOW-VEH > 0
Body Type = 78 (unknown medium/heavy truck) & TOW-VEH > 0
Body Type = 79 (unknown truck type) & 1 $\le$ TOW_VEH $\le$ 4

<u>FARS Single-Unit Truck</u>:

Body Type = 61 (single-unit straight truck, GVWR 10,000-29,500) & TOW-VEH = 0 or 9
Body Type = 62 (single-unit straight truck, GVWR 19,500-26,000) & TOW-VEH = 0 or 9
Body Type = 63 (single-unit straight truck, GVWR over 26,000) & TOW-VEH = 0 or 9
Body Type = 64 (single-unit straight truck, GVWR unknown) & TOW-VEH = 0 or 9
Body Type = 71 (unknown medium truck, GVWR 10,000-26,000) & TOW-VEH = 0 or 9
Body Type = 72 (unknown heavy truck, GVWR over 26,000) & TOW-VEH = 0
Body Type = 78 (unknown medium/heavy truck) & TOW-VEH = 0

APPENDIX B: PROBLEM SIZE ASSESSMENT: ALL CRASHES

This chapter presents crash problem size assessment statistics for the "universe" of crashes. Primary estimates are provided based largely on 1991 GES and FARS data.

For each data source, estimates are provided for all vehicle types, crashes involving passenger vehicles (automobiles, light trucks, vans), and crashes involving combination-unit trucks. Note that the passenger vehicle and combination-unit truck crash and' injury counts do ***not*** sum to equal the "all vehicles" values. Some vehicle types (i.e., medium/heavy single-unit trucks, motorcycles and buses) are included in "all vehicles" but not either of the other two columns. Also, a crash (or injury/fatality occurring in a crash) involving both a passenger vehicle and a combination-unit truck would be counted in ***both*** columns, but only once in the "all vehicles" column. This "double counting" would extend to the rate and likelihood statistics; a passenger vehicle/combination-unit truck crash would be counted in the numerators of both columns, but the associated denominators (VMT and registrations) would reflect only passenger vehicles and combination-unit trucks.

Appendix A described in detail the target crash problem size statistics used in this report and how they are derived. Table B-l summarizes key 1990 and 1991 statistical findings and associated estimates derived as described in Appendix A. Table B-l indicates that, overall police-reported crashes, fatalities, non-fatal injuries and urban divided highway crashes (per the GES "Percent Rural" variable) decreased between 1990 and 1991. Table B-2 provides more detailed 1991 statistics for all vehicles, passenger vehicles, and combination-unit trucks.

Standard errors of estimate for 1991 GES-based statistics may be derived through interpolation of the values presented in the tables contained in Appendix A.

TABLE B-l: SUMMARY OF KEY STATISTICS AND ASSOCIATED ESTIMATES FOR ALL CRASHES, ALL VEHICLE TYPES

Statistic	1990	1991
Police-Reported Crashes (GES)	6.46 million	6.11 million
Vehicles Involved in Police-Reported Crashes (GES)	113 million	10.7 million
Fatalities (FARS)	44,599	41,508
Non-Fatal Injuries in PR Crashes (GES)	333 million	3.10 million
Non-Police Reported Crashes (Miller, 1991)	7.77 million*	7.77 million*
Urban Divided Highway Crashes (PR+NPR; see Chpt 2 for Estimation Method)	2.23 million	2.22 million
Crash-Caused Vehicle-Hours Delay (PR+NPR; see Chpt 2 for Estimation Method)	460.2 million hours	450.2 million hours

* Same estimate used for 1990 and 1991 NPR crashes (from Miller, 1991)

In this appendix presenting statistics on all crash types combined, the involvement rate and "likelihood" statistics (i.e., involvement rate per 100 million VMT, annual involvements per 1,000 vehicles, and expected number of involvements over vehicle life) are based on all crash involvements, regardless of vehicle role. Note, however, that in the report chapters on lane change/merge crashes, involvement statistics are based on subject vehicle (e.g., lane changing/merging vehicle) involvements only. For any crash type, the subject vehicle is the crash-involved vehicle that, if equipped with the countermeasure, could potentially have prevented the crash (see Section A.2, Item 5). However, since the subject vehicle cannot be defined for all crash types combined, the involvement statistics in Table B-2 are based on all involvements, ***regardless of the vehicle's role.***

In comparing the crash experiences of the different vehicle types shown in Table B-2, the most revealing statistics are those that contrast the passenger vehicle crash experience with that of combination-unit trucks. In 1991, Combination-unit truck had a crash involvement ***rate*** (per 100 million vehicle miles traveled) that was 40 percent of the passenger vehicle rate. In contrast, their ***likelihood*** of involvement in crashes (as shown by statistics on annual involvements per 1,000 vehicles and expected number of involvements during vehicle life) was 249 percent of the passenger vehicle likelihood.

TABLE B-2
PROBLEM SIZE ESTIMATE: ALL CRASHES
INVOLVED VEHICLE TYPES: ALL VEHICLES,
PASSENGER VEHICLES, COMBINATION-UNIT TRUCK!3 AND SINGLE-UNIT TRUCKS

GES/FARS-Based Statistics (1991)		*All* Vehicles	Passenger Vehicles	Combination -Unit Trucks	Single-Unit Trucks
Annual # PR Crashes (GES)	Total:	6,110,000	5,966,000	190,000	130,000
	Injury:	2,037,000	1,981,000	45,000	34,000
	PDO:	4,073,000	3,985,000	146,000	96,000
Annual # Fatalities (FARS)		41,508	38,173	3,642	1,162
AM. # Non-Fatal PR Injuries (GES)	Total:	3,097,000	3,027,000	63,000	48,000
	A:	442,000	425,000	14,000	7,000
	B:	879,000	846,000	19,000	13,000
	C:	1,775,000	1,757,000	30,000	28,000
Fatal Crash Equivalents (FCEs)		91,827	86,533	4,492	1,964
Involvement Rate Per 100 Million VMT		493.1	508.6	204.4	244.2
Annual Involvements Per 1,000 Vehicles		55.63	56.11	123.51	30.90
Expected # Involvements During Vehicle life		0.7304	0.7299	1.8157	0.4543
Estimated Annual # NPR Crashes	Total:	7,770,000	7,603,000	278,000	183,000
	Injury:	917,000	897,000	33,000	22,000
	PDO:	6,853,000	6,706,000	245,000	161,000
Estimated Total Annual Crashes (PR + NPR)	Total:	13,880,000	13,.569,000	468,000	313,000
	UDH:	2,223,000	2,180,000	144,000	51,000
	Non-UDH:	11,657,000	11,389,000	324,000	262,000
Crash-Caused Congestion (Delay)	Veh-Hours:	450.2 M	441.1 M	27.0M	10.0 M

Legend:

A	Incapacitating Injuries
B	Nonincapacitating Injuries
C	Possible Injuries
FARS	Fatal Accident Reporting System
FCE	Fatal Crash Equivalent
GES	General Estimates System
M	Million
NPR	Non-Police Reported
PDO	Property Damage Only
PR	Police Reported
UDH	Urban Divided Highway
VMT	Vehicle Miles Travel

This apparent paradox is due to the much greater crash ***exposure*** of trucks; i.e., their average annual vehicle miles traveled is approximately six times that of passenger vehicles. In addition, combination-unit truck crashes are more likely to be severe; in 1991 there were approximately 19.1 fatalities per 1,000 police-reported truck crashes, versus approximately 6.3 fatalities per 1,000 police-reported passenger vehicle crashes. The greater likelihood of truck involvement in crashes, together with the greater average severity of these crashes, makes combination-unit trucks an attractive test bed for crash avoidance countermeasures.\

The statistic "Fatal Crash Equivalents" (FCEs) Was defined in Appendix A (e.g. Table A-l). The value of 91,826.7 FCEs shown in Table B-2 for all vehicles was derived from statistics on 1991 GES non-fatal crash severity (various levels) and 1991 FARS fatal crashes to as shown in Table B-3. Final value of total FCEs is rounded to nearest unit.

TABLE B-3: FATAL CRASH EQUIVALENTS (FCEs) FOR ALL CRASHES, ALL VEHICLE TYPES

"FATAL CRASH EQUIVALENT"			
Crash Severity	**# of Crashes**	**FCE Value**	**Total FCEs**
Fatality (K, 4)	36,937	1.0000	36,937.0
Incapacitating (A, 3)	327,046	0.0840	27,471.9
Non-incapacitating (B, 2)	620,214	0.0178	11,039.8
Possible Injury (C, 1)	1,060,375	0.0093	9,861.5
No injury (O, 0)	4,072,787	0.0016	6,516.5
All Crashes, All Vehicles	6,117,359		**91,826.7**

As noted in Appendix A, the statistics provided for non-police-reported (NPR) crashes, urban divided highway crashes (pR+NPR) and crash-caused delay are based on new estimation techniques that have not been verified. Thus, they should be regarded as very rough estimates. Although these statistics are rough, they will be useful in comparing difficult-to-quantify aspects of the various crash types; i.e., the proportion of NPR crashes they represent and crash-caused traffic delay they cause.

In addition to the problem size assessment statistics presented in this appendix, various descriptive statistics of "all crashes" were derived and considered in relation to the rear-end crash statistics. A presentation of these statistics for "all crashes" is beyond the scope of this report. The reader is referred to the GES and FARS annual reports.

APPENDIX C: GENERALIZED ESTIMATED SAMPLING ERRORS FOR 1991 GES

This appendix presents tables for estimating sampling errors for 1991 GES estimates. These tables (and the narrative explanation below) are taken from the "Technical Note for 1989, 1990, 1991 National Accident Sampling System General Estimates System" (DOT HS 807 796, February, 1992).

The General Estimates System (GES) is based on a probability sample of approximately 43,000 motor vehicle police traffic accident reports selected on an annual basis. GES is ***not*** a census of all 6.1 million police-reported crashes in the U.S. Consequently, GES estimates are subject to sampling errors, as well as nonsampling errors.

Sampling errors are the differences that can arise between results derived from a sample and those computed from observations of all units in the population being studied. Since GES data are derived from a probability sample, estimates of the sampling error can be made.

The tables provided in this appendix can be used to calculate confidence intervals about the GES estimates. Tables are provided for crash, vehicle, and people (e.g., number of injuries) estimates. The numbers in the tables represent estimates of one standard error. If all possible samples of PARS were selected (under the same conditions), then approximately 68 percent of the intervals from one standard error below the estimate to one standard error above the estimate would include the average of all possible samples. Thus, the interval between one standard error below the estimate and one standard error above the estimate constitutes a 68 percent confidence interval. An interval of two standard errors above and below the estimate is a 95 percent confidence interval.

The best method for calculating standard errors is to use the natural logarithmic function provided for each estimate type. However, linear interpolation may also be used. For example, from the crash (Table C-l) standard error values for 300,000 and 400,000, the standard error for 350,000 is approximated at 25,600. The 68 percent confidence interval for this estimate would be 350,000 ± 25,600 or 324,400 to 375,600.

TABLE C-l:

1991 CRASH ESTIMATES AND STANDARD ERRORS

Estimate (x)	One Standard Error (SE)*	Estimate (x)	One Standard Error (SE)*
1,000	700	600,000	40,000
5,000	1,400	700,000	45,700
10,000	2,100	800,000	51,200
20,000	3,300	900,000	56,700
30,000	4,200	1,000,000	62,200
40,000	5,100	2,000,000	116,200
50,000	5,900	3,000,000	169,800
60,000	6,800	4.000.000	223,700
70,000	7,500	5,000,000	278,000
80,000	8,300	6,000,000	332,800
90,000	9,000	7,000,000	388,100
100,000	9,700	8,000,000	444,000
200,000	16,400	9,000,000	500,400
300,000	22,600	10,000,000	557,300
400,000	28,600	11,000,000	614,700
500,000	34,400	12,000,000	672,500

$$*SE=e^{\frac{a}{2}+\frac{b}{2}[\ln(x)]^2},$$ *where*

a=9.93401

b=0.06362

TABLE C-2:

1991 VEHICLE ESTIMATES AND STANDARD ERRORS

Estimate (x)	One Standard Error (SE)*	Estimate (x)	One Standard Error (SE)*
1,000	400	600,000	39,900
5,000	1,000	700,000	46,100
10,000	1,600	800,000	52,200
20,000	2,500	900,000	58,400
30,000	3,400	1,000,000	64,700
40.000	4,200	2.000.000	128.300
50,000	4,900	3,000,000	194,500
60,000	5,700	4,000,000	263,100
70,000	6,400	5,000,000	334,000
80,000	7,100	6,000,000	406,900
90,000	7,800	7,000,000	481,600
100,000	8,500	8,000,000	558,200
200,000	15,000	9,000,000	636,400
300,000	21,300	10,000,000	716,100
400,000	27,500	11,000,000	797,400
500,000	33,700	12,000,000	880,100

$$*SE = e^{\frac{a}{2} + \frac{b}{2}[\ln(x)]^2}$$, *where*

a=8.83524
b=0.06977

TABLE C-3:

1991 PERSON ESTIMATES AND STANDARD ERRORS

Estimate (x)	One Standard Error (SE)*	Estimates	One Standard Error (SE)*
1,000	400	600,000	34,800
5,000	1,000	700,000	40,100
10,000	1,500	800,000	45,300
20,000	2,400	900,000	50,600
30,000	3,100	1,000,000	55,800
40,000	3,900	2,000,000	108,800
50,000	4,500	3,000,000	163,200
60,000	5,200	4,000,000	219,100
70,000	5,800	5,000,000	276,400
80,000	6,500	6,000,000	335,000
90,000	7,100	7,000,000	394,900
100,000	7,700	8,000,000	455,900
200,000	13,400	9,000,000	518,100
300,000	18,900	10,000,000	581,300
400,000	24,300	11,000,000	645,500
500,000	29,600	12,000,000	710,600

APPENDIX D: REFERENCES

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