Technical Report Documentation Page

1. Report No. DOT HS 807 994	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle REAR-END CRASHES: PROBLEM SIZE ASSESSMENT AND STATISTICAL DESCRIPTION		5. Report Date May, 1993
		6. Performing Organization Code
7. Author(s) Ronald R. Knipling, NHTSA; Jing-Shiarn Wang, IMC, Inc.; Hsiao-Ming Yin, IMC, INC.		8. Performing Organization Report No.
9. Performing Organization Name and Address Office of Crash Avoidance Research, National Highway Traffic Safety Administration, 400 Seventh Street, SW, Washington, DC 20590		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Crash Avoidance Research, National Highway Traffic Safety Administration, 400 Seventh Street, SW, Washington, DC 20590		13. Type of Report and Period Covered Technical report
		14. Sponsoring Agency Code NHTSA/NRD-50

15. Supplementary Notes

Based in part on research performed by Information Management Consultants, Inc. under Contract No. DTNH-22-91-C-03121.

16. Abstract

This document presents problem size assessments and statistical crash descriptions for rear-end crashes, including two key subtypes: lead-vehicle stationary (LVS) and lead-vehicle moving (LVM). Principal data sources are the 1990 General Estimates System (GES) and Fatal Accident Reporting System (FARS). Rear-end crashes are a potential "target crash" of high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. In this report, the rear-end 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 three vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans), and combination-unit trucks. LVS and LVM rear-end 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.

17. Key Words Traffic Accidents, Rear-End Crashes, Crash Avoidance Countermeasures, Combination-Unit Trucks, IVHS, Traffic Crash Statistics.	18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, VA 22161

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

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150182

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EXECUTIVE SUMMARY

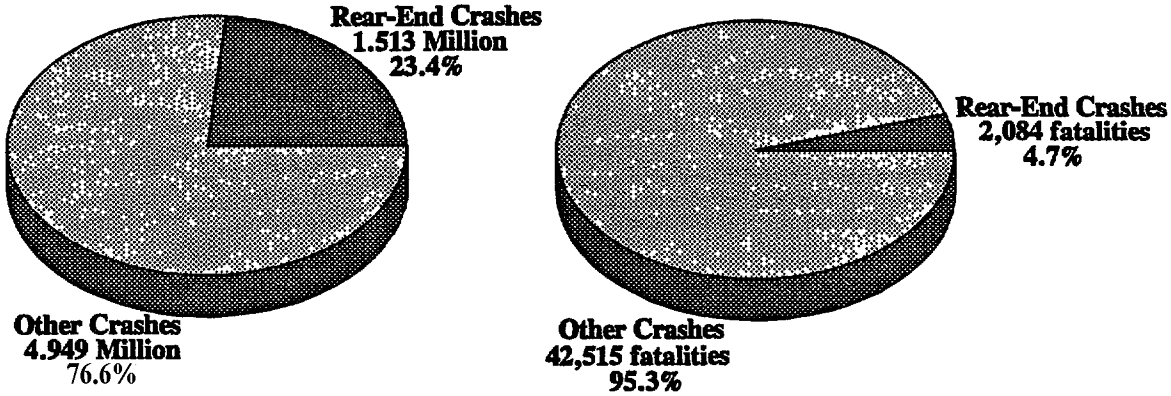
This document presents problem size assessments and statistical crash descriptions for rear-end crashes, including two key subtypes: lead-vehicle stationary (LVS) and lead-vehicle moving (LVM). Principal data sources are the 1990 General Estimates System (GES) and Fatal Accident Reporting System (PARS). Rear-end crashes are a potential "target crash" of high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures, in particular *headway detection* systems that detect stopped or slowly-moving vehicles in a vehicle's forward travel path.

In this report, the rear-end 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 three vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans), and combination-unit trucks. LVS and LVM rear-end 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.

Principal statistical findings regarding the rear-end problem size include the following:

- In 1'990, there were approximately 1.5 million police-reported, rear-end crashes with 2,084 associated fatalities.
- There were approximately 844,000 associated injuries, including 68,000 serious (incapacitating) injuries.
- Rear-end crashes constitute about 23 percent of all police-reported crashes, but only about 4.7 percent of all fatalities. **Figure ES-1** shows the rear-end crash and fatality statistics in relation to all crashes and crash fatalities.

FIGURE ES-1



- During its operational life, a vehicle can be expected to be involved in 0.18 police-reported (PR) rear-end crashes; one-half (0.09) as the striking vehicle and one-half as the struck vehicle.

- The above statistics relate to police-reported crashes. This report presents a method for estimating annual ***non-police reported*** (NPR) rear-end crashes which yields an estimate of 1.76 million.

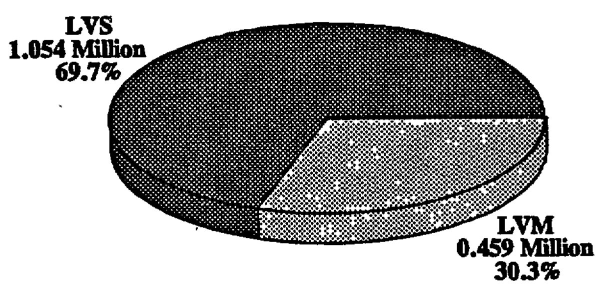
- The report also presents a method for estimating crash-caused delay in vehicle-hours. Based on the estimation algorithm described in the report, rear-end crashes cause approximately 144 million vehicle-hours of delay annually. This is about one-third of *all* crash-caused delay.

The above statistics relate to all vehicle types combined. The report presents statistics on major vehicle type categories, including passenger vehicles (here defined as cars, light trucks, and vans) and combination-unit trucks (i.e., tractor-trailers). These statistics are further disaggregated by vehicle role (i.e., striking versus struck). Comparisons between passenger vehicles and combination-trucks are notable. For example, less than 2 percent of all rear-end crashes involve a combination-unit truck as the striking unit, and combination-unit trucks have a much lower *rate* of involvement per vehicle mile traveled (VMT) than do passenger vehicles. However, due to their greater exposure (average miles traveled), combination-unit trucks have a much higher ***expected number*** of involvements in target crashes during their operational lives than do passenger vehicles; i.e., an average of 0.18 involvements as the striking vehicle in police-reported rear-end crashes versus 0.09 for passenger vehicles. Moreover, rear-end crashes involving a combination-unit truck (either as the striking or struck vehicle) are much more likely to result in a fatality than are crashes involving only passenger vehicles.

An important classification within the rear-end crash category whether the lead-vehicle is stationary (LVS) or moving (LVM). These two types of rear-end crashes are different in many respects. There are more than twice as many LVS crashes as LVM crashes (see Figure ES-2). However, LVM crashes, though less frequent, are somewhat more severe on average than are LVS crashes. Still, LVS crashes constitute the larger overall problem in terms of crashes, injuries, and fatalities.

FIGURE ES-2

All Rear-End Crashes: 1.513 Million



The statistical characteristics of rear-end crashes in GES do not reveal widespread distinctive patterns of occurrence such as roadway or environmental factors. Most crashes (both LVS and LVM) occur during daylight hours on dry, straight roadways. The most common coded pre-crash vehicle maneuver for the striking vehicle is simply "going straight" (89 percent overall). For LVM crashes, accident type data indicate that "lead-vehicle slower" and "lead-vehicle decelerating" subtypes are approximately equal in frequency. Across all rear-end crashes, about 10 percent of lead vehicles are in the process (or have the intent) of making a left turn and about 5 percent a right turn. Obstruction of driver vision is rarely noted.

Notable differences in the conditions of occurrence of LVS and LVM crashes include the fact that most LVM crashes (54 percent) are non-junction crashes (i.e., not intersection or intersection-related), whereas only 35 percent of LVS crashes are non-junction. In addition, LVM crashes are somewhat more likely to occur on divided highways and other higher-speed roadways than are LVS crashes.

Rear-End crash involvement rates (per 100 million VMT) were calculated for various driver age and sex groups, both for the striking and struck vehicle roles. The largest involvement rates were found for younger drivers (age 15 to 19) in either striking or struck vehicles. Male and female drivers showed a different crash involvement pattern regarding vehicle role. Overall, female drivers had higher involvement rate than males as the struck vehicle driver, whereas the involvement rates as the striking vehicle driver were approximately equal for male and female.

Indiana Tri-Level study (Treat *et al*, 1979) findings on the causal factors associated with 45 LVS and 12 LVM crashes (of the 420 total cases in the T&Level in-depth sample) were accessed. The analysis of the T&Level cases by crash type was possible through the use of an enhanced Tri-Level study data file developed by NHTSA (1990). The Tri-Level statistics portray rear-end crashes as resulting largely from driver inattention and other forms of delayed recognition (i.e., conscious driver does not properly perceive, comprehend, and/or react to vehicle in his or her forward travel path). There is little involvement of vehicle factors, indirect human causes (e.g., alcohol), or environmental factors. This pattern is true for both LVS and LVM crash subtypes.

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 1990 GES, and reference citations.

1. INTRODUCTION

This document presents problem size assessments and statistical crash descriptions for rear-end crashes and two major subtypes of rear-end crashes. Rear-end crashes are a major "target crash" of various high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. In this report, rear-end 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). Rear-end 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 rear-end 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 rear-end crashes. This related analytical countermeasure modeling work is described in a technical report by Knipling *et al* (1993). The principal countermeasure concept examined by Knipling *et al* is a headway detection system that would detect stopped or slower-moving vehicles in a vehicle's forward travel path.

This document provides statistics on current rear-end crash problem size and statistics describing the conditions of occurrence and, to a limited extent, the causes of rear-end crashes. Most statistics provided are estimates based on national crash databases, such as the 1990 NHTSA General Estimates System (GES). Applicable crash fatality counts from the 1990 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 rear-end crash population is provided based on a new estimation procedure.

The provision of crash statistics for rear-end 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 rear-end crashes, the report will initially present the entire rear-end crash population and then disaggregate the overall problem into ***two*** subtypes ***lead-vehicle stationary*** (LVS) and ***lead-vehicle moving*** (LVM). The countermeasure analytical modeling work described above (Knipling ***et al,*** 1993) addresses these two subtypes separately, 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 defines rear-end crashes (per major NHTSA crash databases) and presents data on rear-end crash problem size.
- Chapter 3 disaggregates the rear-end crash problem size into two major subtypes: lead-vehicle stationary (LVS) and lead-vehicle moving (LVM). Chapter 3 then provides problem size statistics on these subtypes.
- Chapter 4 provides descriptive statistics regarding all rear-end crashes and the two major subtypes. This includes crash involvement rates for various driver age and gender groups.
- Chapter 5 recounts statistics from the Indiana Tri-Level study on the causes of LVS and LVM rear-end crashes.
- Chapter A defines and describes the derivation of statistics used to quantify and describe the rear-end and other target crash problems.
- Chapter 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. REAR-END CRASH PROBLEM SIZE

This chapter provides problem size statistics for rear-end crashes, including those involving passenger vehicles and combination-unit trucks in each of the two major collision roles: striking vehicle and struck vehicle. The reader is referred to Appendix A for a detailed explanation of each of the statistics used in the chapter. In addition, the reader is referred to Appendix B for a problem size assessment of all crashes -- i.e., the "universe" of crashes of which rear-end crashes are a part.

Table 2-1 provides a problem size assessment for all on-roadway rear-end crashes in accordance with the following data specifications listed below. Note that a previous analysis (of 1989 GES data) showed that more than 99 percent of rear-end crashes are "on roadway."

GES Estimates (1990):

Imputed Manner of Collision (A07I, MANCOL-I) = 1 (Rear-End)

Relation to Roadway (A10, REL_Rwy = 1 (On-Roadway).

FARS Estimates (1990):

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

Relation to Roadway @EL-ROAD) = 1 (On-Roadway).

Table 2-l provides problem size assessments for these crashes with the following vehicle type/role specifications:

- All vehicle types
- Passenger vehicle as striking vehicle (i.e., vehicle with Vehicle Role = 1 (Striking) is passenger vehicle)
- Passenger vehicle as struck vehicle (i.e., vehicle with Vehicle Role = 2 (Struck) or 3 (Both Striking or Struck) is passenger vehicle)
- Combination-unit truck as striking vehicle (i.e., vehicle pith Vehicle Role = 1 (Striking) is combination-unit truck)
- Combination-unit truck as struck vehicle (i.e., vehicle with Vehicle Role = 2 (Struck) or 3 (Both Striking or Struck) is combination-unit truck).

TABLE 2-1
PROBLEM SIZE ESTIMATE - REAR-END CRASHES ON ROADWAY INVOLVED VEHICLE TYPE/ROLE: PV STRIKING, PV STRUCK, COMB STRIKING, COMB STRUCK

GES/FARS-Based Statistics (1990)

		All On-Road Rear-End	PV Striking	PV Struck	Comb Trk Striking	Comb Trk Struck
Annual # PR Crashes (GES)	Total:	1,513,000	1,450,000	1,467,000	25,000	17,000
	Injury:	535,000	510,000	516,000	9,000	7,000
	PDO:	979,000	940,000	951,000	17,000	10,000
Annual # Fatalities (FARS)		2,084	1,569	1,352	332	487
Ann. # Non-Fatal PR Injuries (GES)	Total:	844,000	807,000	815,000	14,000	10,000
	A:	68,000	63,000	61,000	2,000	2,000
	B:	150,000	141,000	142,000	3,000	3,000
	C:	627,000	602,000	612,000	10,000	5,000
Fatal Crash Equivalents		13,385	12,392	12,160	570	502
Percentage of All PR Crashes		23.41%	23.02%	23.29%	11.40%	7.51%
Percentage of All FCE		14.89%	14.38%	14.11%	11.68%	10.27%
Percentage of All Fatalities		4.67%	3.84%	3.31%	7.87%	11.55%
Involvement Rate Per 100 Million VMT		154.8	73.2 *	74.0 *	26.3 *	17.3 *
Annual Involvements Per 1,000 Vehicles		17.23	7.96 *	8.05 *	15.80 *	10.41 *
Expected # Involvements During Vehicle Life		0.2262	0.1035 *	0.1047 *	0.2323 *	0.1531 *
Estimated Annual # NPR Crashes	Total:	1,764,000	1,407,000	1,424,000	24,000	14,000
	Injury:	208,000	166,000	168,000	3,000	2,000
	PDO:	1,556,000	1,241,000	1,256,000	21,000	13,000
Estimated Total Annual Target Crashes (PR + NPR)	Total:	3,277,000	2,857,000	2,891,000	49,000	31,000
	UDH:	711,000	612,000	624,000	16,000	11,000
	Non-UDH:	2,566,000	2,245,000	2,266,000	33,000	20,000
Crash-Caused Congestion (Delay)	Veh-Hours:	144.1M	130.1M	132.7M	3.3M	2.4 M
Percentage of All Crash-Caused Delay		31.31%	28.27%	28.84%	0.72%	0.52%

* Involvements as subject vehicle only (i.e., involvements in crash role defined).

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

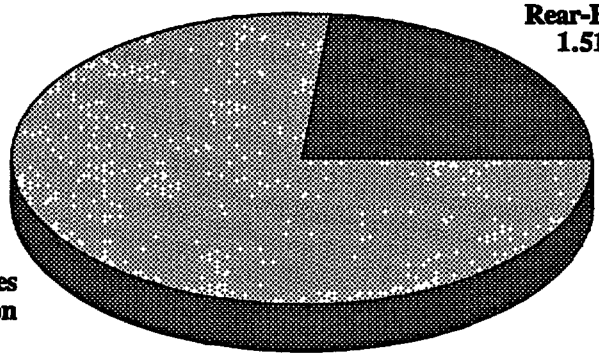
Note that the above subtypes are overlapping and therefore not additive; e.g., the PV striking and PV struck columns add to more than the all vehicles column, since most rear-end crashes involve both a PV striking and a PV struck. Note also that the involved statistics for PV-striking, PV-struck, truck-striking and truck-struck are based on involvements as subject vehicle - i.e. involvements in the role defined (i.e., striking or struck).

Table 2-l (and follow-up calculations) show that:

- In 1990, there were approximately 1.5 million annual police-reported rear-end crashes on roadways (Standard Error = 90,000). Also see **Figure 2-l.**

FIGURE 2-1

All Crashes: 6.462 Million



- In 1990, there were 2,084 associated fatalities, a large number of which involved combination-unit trucks either as the striking unit (15.9 percent) or as the struck unit (23.4 percent).
- There were approximately 844,000 associated injuries, most of relatively mild severity (Standard Error = 47,600).
- In 1990, rear-end crashes were associated with approximately 13,385 fatal crash equivalents (see Appendix A for definition).
- Rear-end crashes constituted about 23.4 percent of all police-reported crashes, 14.9 percent of total fatal crash equivalents, but only about 4.7 percent of all fatalities.

- During its operational life, a vehicle can be expected to be involved in 0.2262 PR rear-end crashes regardless of the vehicle's role. About half of the 0.2262 involvements would be in the striking role, and about half would be in the struck role.

- Per the non-police-reported crash estimation algorithm (see Appendix A), there are approximately 1.8 million annual NPR rear-end crashes.

- About 711,000 rear-end crashes (PR + NPR) occurred on urban divided highways. This was about one-third of *all* UDH crashes (see Tables 3-1 and 3-2). Primarily because of their frequent occurrence on UDHs, rear-end crashes account for a large percentage (32.1 percent) of all crash-caused delay.

- Comparing the vehicle type/role statistics to the overall PR rear-end crash problem, one finds that:
  95.8 percent of rear-end crashes involve a striking passenger vehicle.
  97.0 percent involve a struck passenger vehicle
  1.7 percent involve a striking combination-unit truck (however, 15.9 percent of the rear-end fatalities are associated with this crash type).
  1.1 percent involve a struck combination-unit truck (however, 23.4 percent of the rear-end fatalities are associated with this crash type).

- Compared to passenger vehicles, combination-unit truck rear-end crashes accounted for a relative high percentage of all combination-unit truck crash fatalities (7.9 percent and 11.6 percent for striking and struck, respectively (based on comparison of Table 2-l data with 1990 all-crash data in Table 3-2).

- The 1989 fatality statistics (FARS) for rear-end crashes are provided for comparison to the 1990 statistics (note: 1989 statistics are not shown in Table 2-l):
  All vehicle types: 1990: 2,084; 1989: 2,071.
  Passenger vehicle as striking vehicle: 1990: 1,569; 1989: 1,572.
  Passenger vehicle as struck vehicle: 1990: 1,352; 1989: 1,292,
  Combination-unit truck as striking vehicle: 1990: 332; 1989: 331.
  Combination-unit truck as struck vehicle: 1990: 487; 1989: 484.

- Combination-unit trucks have much lower rates (per vehicle miles travled) of involvement in these crashes than do passenger vehicle (whether as the striking or struck vehicle), but their *likelihood* is considerably greater for the striking vehicle role in these crashes. The average combination-unit truck can be expected to be involved in 0.18 PR rear-end crashes as the striking vehicle during its-operational life, and 0.12 crashes as the struck vehicle.

- The expected number of fatalities from rear-end crashes during vehicle operational life is many times higher for combination-unit trucks than for passenger vehicles. Based on 1990 FARS statistics and registrations projected over the life of the average vehicle, the expected number of rear-end crash fatalities per vehicle produced are the following for combination-unit trucks and passenger vehicles in the striking and struck roles (note: statistics not shown in Table 2-1):
  - Fatalities occurring in crashes involving a striking passenger vehicle: 98 per million PVs produced
  - Fatalities occurring in crashes involving a striking combination-unit truck: 2,396 per million trucks produced
  - Fatalities occurring in crashes involving a struck passenger vehicle: 83 per million PVs produced
  - Fatalities occurring in crashes involving a struck combination-unit truck: 3,515 per million trucks produced.

  The striking- and struck-vehicle fatalities per million vehicles produced statistics are 24 and 42 times greater respectively for combination-unit trucks than for passenger vehicles.

3. LVS AND LVM PROBLEM SIZE

An important classification within the rear-end crash category is whether the lead vehicle is stationary (LVS) or moving (LVM). These two types of rear-end crashes are different in many respects. Table 3-1 presents problem size statistics for LVS, LVM, and all rear-end crashes for all vehicle types combined. In the original data retrievals, a small percentage of rear-end crashes were classified as ***neither*** LVS or LVM; for simplicity, these were distributed proportionately between LVS and LVM so that the current LVS and LVM statistics sum to equal the total rear-end crash values (i.e., the same totals presented in Table 2-l). Note also that fatality estimates for LVS and LVM crashes are based on GES, since FARS does not contain the Accident Type variable. The 1990 GES retrieval specification (for all vehicle types) is as follows:

All on-road rear-end crashes (same as in Chapter 2):

Imputed Manner of Collision (A07I, MANCOL-I) = 1 (Rear-End)

Relation to Roadway (A10, REL-RWY) = 1 (On-Roadway).

Rear-end, lead-vehicle stationary (LVS) rear-end crashes:

Manner of Collision (A07I, MANCOL-I) = 1 (Rear-End)

Relation to Roadway (A10, REL-RWY) = 1 (On-Roadway).

Accident type (V23) of striking vehicle (vehicle with Imputed Vehicle Role = 1 [Striking]) = 20

Rear-end, lead-vehicle moving (LVM) crashes were defined as follows:

Imputed Manner of Collision (A07I, MANCOL-I) = 1 (Rear-End)

Relation to Roadway (A10, REL-RWY) = 1 (On-Roadway).

Accident type (V23) of striking vehicle (vehicle with Imputed Vehicle Role = 1 [Striking]) = 24, 28

The only FARS (1990) statistic in Table 3-1 is the fatality statistic for all rear-end crashes. This is based on the same specification as previously (see Chapter 2). Note that the involvement statistics in Table 3-l include all involvements in target crashes, regardless of vehicle role (i.e., striking or struck).

TABLE 3-1
PROBLEM SIZE ESTIMATE - REAR-END CRASHES ON ROADWAY INVOLVED VEHICLE TYPES/ROLES: ALL VEHICLES, LEAD VEHICLE STATIONARY, LEAD VEHICLE MOVING

GES/FARS-Based Statistics (1990)

		All On-Road Rear-End	Rear-End LVS	Rear-End LVM
Annual # PR Crashes (GES)	Total:	1,513,000	1,054,000	459,000
	Injury:	535,000	379,000	155,000
	PDO:	979,000	674,000	304,000
Annual # Fatalities	GES:	2,985	1,647	1,338
	FARS:	2,084		
Ann. # Non-Fatal PR Injuries (GES)	Total:	844,000	599,000	245,000
	A:	68,000	40,000	27,000
	B:	150,000	107,000	43,000
	C:	627,000	452,000	174,000
Fatal Crash Equivalents (FCEs)		13,385	8,511	4,874
Percentage of All PR Crashes		23.41%	16.31%	7.11%
Percentage of All FCEs		14.89%	9.47%	5.42%
Percentage of All Fatalities		4.67%		
Involvement Rate Per 100 Million VMT		154.8	107.6	47.2
Annual Involvements Per 1,000 Vehicles		17.23	11.97	5.26
Expected # Involvements During Vehicle Life		0.2262	0.1572	0.0690
Estimated Annual # NPR Crashes	Total:	1,764,000	1,216,000	549,000
	Injury:	208,000	143,000	65,100
	PDO:	1,556,000	1,072,000	484,000
Estimated Total Annual Target Crashes (PR + NPR)	Total:	3,277,000	2,269,000	1,008,000
	UDH:	711,000	445,000	267,000
	Non-UDH:	2,566,000	1,825,000	741,000
Crash-Caused Congestion (Delay)	Veh-Hours:	144.1 M	91.7 M	52.4 M
Percentage of All Crash-Caused Delay		31.30%	19.93%	11.39%

Legend:

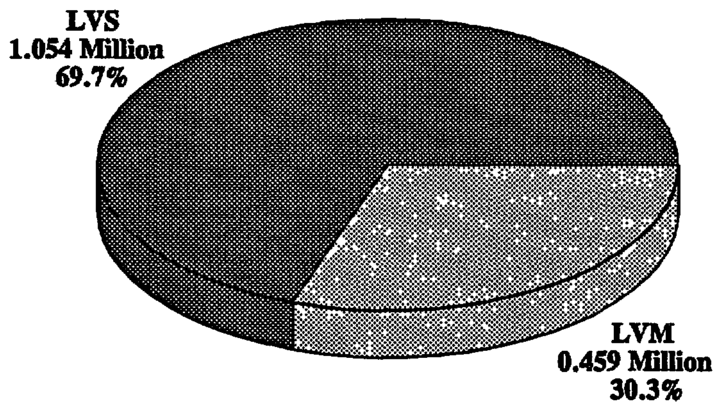
A	Incapacitating Injuries	M	Million
B	Nonincapacitating Injuries	NPR	Non-Police Reported
C	Possible Injuries	PDO	Property Damage Only
FARS	Fatal Accident Reporting System	PR	Police Reported
FCE	Fatal Crash Equivalent	UDH	Urban Divided Highway
GES	General Estimates System	VMT	Vehicle Miles Traveled

Table 3-l shows that there were more than twice as many LVS crashes as LVM crashes. According to GES, in 1990 there were **(see Figure 3-l):**

- 1.05 million police-reported (PR) LVS crashes (Standard Error = 65,000)
- 0.46 million PR LVM crashes (Standard Error = 32,000).

FIGURE 3-l

All Rear-End Crashes 1.513 Million



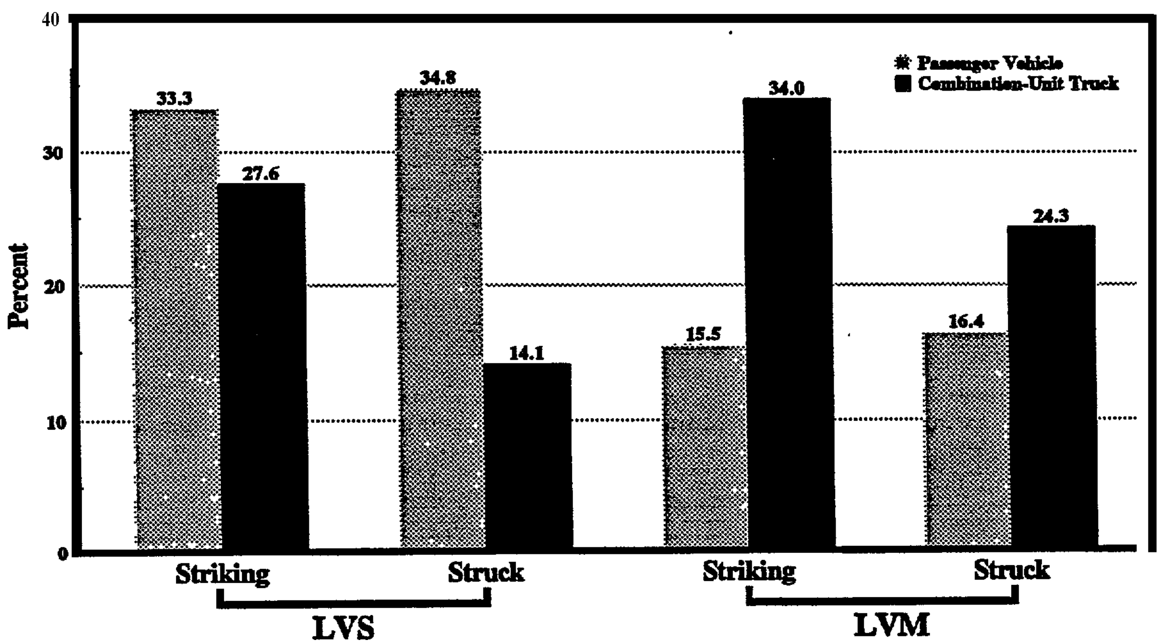
There were also more fatalities (as indicated by GES fatality statistics) associated with LVS crashes, although the ratio was considerably less (1,647 vs. 1,338). In other words, the ratio of fatalities to crashes was greater for LVM crashes (0.0029 fatalities per police-reported LVM crash) than for LVS crashes (0.0016 fatalities per police-reported LVS crash; ratios not shown in Table 3-l).

Similarly, the ratio of incapacitating ("A") injuries to PR crashes was greater for LVM (0.059) than for LVS crashes (0.038; ratios not shown in Table 3-l). In short, LVM crashes, though less frequent, were somewhat more severe, on the average, than LVS crashes. Still, LVS crashes constituted the larger problem size in terms of crashes, injuries, and fatalities.

Accident Type data from the NASS Crashworthiness Data System (CDS) were reviewed as a check of the GES LVS versus LVM percentage distribution. CDS is a smaller data file but is based on an in-depth case review by trained accident researchers. For the years 1990-91, the CDS rear-end Accident Type percentages were 67 percent LVS and 33 percent **LVM,** percentages which correspond closely to those from GES.

Figure 3-2 compares the relative crash involvements of two major vehicle types (passenger vehicles and combination-unit trucks) in LVS and LVM crashes. Furthermore, Figure 3-2 shows relative LVS and LVM involvements in the two different vehicle roles, striking and struck. Vehicles that were ***both*** striking and struck (approximately 15.4 percent of the involvements) were included in the struck category, based on the assumption that their primary (i.e., first) role was struck. Two key differences between passenger vehicles and combination-unit trucks are notable. First, for passenger vehicles, LVS crash involvements were approximately twice as frequent as LVM involvements, whereas for combination-unit trucks LVM involvements 'were more frequent. Secondly, passenger vehicles were approximately equally involved in the striking and struck roles, whereas combination-unit trucks were more frequently involved as the striking vehicle. The least frequent role/subtype for passenger vehicles - i.e., the striking vehicle in LVM crashes -- was the most frequent role/subtype for combination-unit trucks.

FIGURE 3-2



4. LVS AND LVM DESCRIPTIVE STATISTICS

GES bivariate distributions were obtained based on the disaggregation defined in . Chapter 3; i.e., LVS, LVM, and all on-road rear-end crashes. All descriptive statistics are for all vehicle types combined. For statistics of particular interest, corresponding percentage distribution charts for all on-road rear-end crashes and its two subtypes (LVS, LVM) are presented at end of this chapter. Note that there was no imputing of vehicle types or the LVS vs. LVM subtypes (i.e., unknowns were not distributed proportionately), since such imputing would add a small amount of error to the statistics. Statistics relating to the following other variables were obtained:

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 (A1CI WKDY-I)
Number of Motor Vehicles (A03, VEH_INVL)
Lane Use (A05, LAND-USE)
Imputed Relation to Junction (A09I, REL_JCT)
Trafficway Flow (All, TRAF_WAY)
Imputed Roadway Alignment (A131, ALIGN_I)
Imputed Roadway Profile (A14I, PROFIL_I)
Imputed Roadway Surface Condition (A15I, SURCON_I)
Hotdeck Imputed Speed Limit (Al8I, SPDLIM_H)
Imputed Light Condition (Al9, LGTCON_I)
Imputed Atmospheric Condition (A20, WEATHR I)
Travel speed (Vll, SPEED) of striking vehicle (vehicle with Imputed Vehicle Role (V22I, VROLEI) = 1 [Striking])
Vehicle Maneuver (V21, MANEUVER) for Striking Vehicle (Imputed Vehicle Role (V22I, VROLEI) = 01)
Vehicle Maneuver (V21, MANEUVER) for Struck Vehicle (Imputed Vehicle Role (V22I, VROLE-I) = 02 or VROLE_I = 03)
Accident Type (V23, ACC_TYPE) for involved vehicles
Violations Charged (D02, VIOLATN) for Driver of Striking Vehicle (Imputed Vehicle Role (V221, VROLEI) = 01)
Driver's Vision Obscured By . . . (D04, VIS OBSC) for Driver of Striking Vehicle (Vehicle Role (V22I, VROLE_I) = 01)
Hotdeck Imputed Age (P7H, AGE-H)
Hotdeck Imputed Sex (P8H, SEX-H)

The following major findings for 1990 are noted (For each specific variable, the percentage cited here is the proportion of it's known value.):

- Most rear-end crashes occurred during daytime hours (6:01-l8:30), with a high number (29.7 percent) occurring during the 3-hour afternoon rush hour period. This is more than twice the percentage (13.9 percent) occurring during the 3.5-hour morning rush hour period. **Figure 4-1** shows that there was little difference between the LVS and LVM distributions.

- Regarding day-of-week, the largest number of crashes occurred on Fridays, the smallest on Sundays. (Little difference, LVS vs. LVM).

- Most rear-end crashes involved two vehicles; however, 12.9 percent involved three vehicles, and 2.1 percent involved four vehicles. (Little difference, LVS vs. LVM).

- About half of rear-end crashes occurred within population areas of 25,000. (Little difference, LVS vs. LVM, see **Figure 4-2).**

- Most (54.2 percent) of LVM crashes were non-junction, whereas only 35.4 percent of LVS crashes were non-junction. About 54.9 percent of *all* rear-end crashes were intersection, intersection-related, or driveway/alley access-related LVS crashes **(Figure 4-3).**

- The majority of crashes for which trafficway flow was known occurred on non-divided highways. About 57.3 percent of LVM crashes (for which trafficway flow was known) occurred on non-divided highways, versus 67.1 percent of LVS crashes **(Figure 4-4).**

- More than 90.0 percent of both LVM and LVS crashes occurred on straight roadways. (Little difference, LVS vs. LVM).

- Most crashes occurred on level roadways. "Hillcrest" was rarely coded. (Little difference, LVS vs. LVM, see **Figure 4-5).**

- The roadway surface condition was dry in 72.0 percent of cases. (Little difference, LVS vs.-LVM, see **Figure 4-6).**

- To illustrate the generally low involvement of environmental factors in these crashes, a retrieval was performed that identified LVS crashes that occurred on roadways that were **not** coded as curved, hilly, icy, or snow-covered. In the 1990 **GES,** 67.2 percent of LVS crashes met this criterion.

- A variety of roadway speed limits were represented. For those roadways in which the speed limit was known, 28.6 percent -of LVM crashes and 13.4 percent of LVS crashes occurred on high speed (55mph+) roadways. The median known speed limit was slightly higher (42mph) for LVM than for LVS crashes (39mph). **Figure 4-7** shows the percentage of different speed intervals.

- Unknown rates for pre-crash travel speed were high -- nearly 70 percent. However, where the striking vehicle travel speed was coded, the median for LVS crashes was 22mph; for LVM crashes it was 32mph. Of striking vehicles for which the travel speed was known (coded), only 2.5 percent of LVS-involved striking vehicles had a pre-crash travel speed of 55mph or greater. For LVM-involved striking vehicles, -14.8 percent were traveling at 55mph or greater.

- About 76.5 percent of crashes occurred during daylight. About 14.2 percent occurred under "dark but lighted" conditions. Six percent occurred on dark (unlighted) roadways. (Little difference, LVS vs. LVM).

- About 78.8 percent of crashes occurred during dry weather; 18.0 percent occurred during rain; and 1.9 percent occurred during snow. (Little difference, LVS vs. LVM).

- Overall, about 0.5 percent of rear-end crashes occurred during fog, with LVS crashes somewhat more likely than LVM crashes to occur during fog (0.6 percent vs. 0.2 percent).

- About two-thirds of rear-end crashes caused no injury. LVM crashes were more likely to be severe, as evidenced by the greater percentage of incapacitating injury ("A") and fatal ("K") crashes (4.6 percent total for LVM, 3.0 percent total for LVS).

- For the striking vehicle in both LVM and LVS crashes, the most common vehicle precrash vehicle maneuvers were:
  - Going straight (88.6 percent overall)
  - Slowing or stopping (6.7 percent overall)

- For the struck vehicle in LVM crashes, the most common vehicle precrash maneuvers were:
  - Slowing or stopping (55.6 percent)
  - Going straight (25.8 percent)
  - Turning left (8.1 percent)
  - Turning right (6.5 percent)

- Not surprisingly, for the struck vehicle in LVS crashes, the most common precrash vehicle maneuver was "stopped" (98.2 percent).

- The Accident Type variable provides information similar to Vehicle Maneuver, but includes a consideration of driver intentions. **Figure 4-8** shows schematically percentage breakouts for lead vehicle actions/ intentions along two dimensions: stopped/slower/decelerating and turning left/going straight/turning right. Within the LVM category, "lead-vehicle slower" crashes are slightly more numerous (16.2 percent) than "lead-vehicle decelerating" crashes (14.1 percent). Across all lead-vehicle stopped/slower/decelerating configurations, about 85 percent of lead-vehicles were going straight, 10 percent turning left, and 5 percent turning right.

  One caveat regarding the LVS versus LVM dichotomy is that some LVS crashes may involve a lead vehicle that has braked to a stop immediately ***prior*** to being struck by a following vehicle (e.g., less than one second before being struck). Such crashes are likely to be more similar to LVM crashes than to other LVS crashes in their pre-crash dynamics. Crashes meeting this description would be coded LVS in GES and cannot be identified separately from other LVS crashes that involve longer periods of time in which the lead-vehicle is stationary. Supplemental studies indicate, however, that the number of such cases is not large; one review of 56 LVS crash case files from the 1991 CDS identified no cases meeting this description (Knipling *et al,* 1993).

- Not surprisingly, rear-end crashes involving lead-vehicle turning are more likely to occur at junctions than at non-junction locations. This is true both for LVS crashes and for the two subtypes of LVM crashes. Most LVS crashes involving lead-vehicle "going straight" occur at junctions, whereas most LVM crashes involving lead-vehicle "going straight" occur at non-junction locations. This is true both for the "lead-vehicle slower" and "lead-vehicle decelerating" LVM subtypes. **Table 4-1** shows Imputed Relation to Junction row percentages for nine rear-end accident subtypes. The "junction" column in Table 4-1 combines data from the Intersection, Intersection-Related, Interchange, Driveway/Alley, and Entrance/Exit Ramp Relation to Junction categories.

- More than half (54.5 percent) of striking vehicle drivers were not charged with any violation. The most common violations charged were (hit & run crashes excluded):
  - "Other violation" (23.7 percent)
  - Speeding (13.7 percent)
  - Alcohol/drugs (3.0 percent).

  (Little difference, LVS **vs.** LVM. **Figure 4-9** shows the most common violations charged among rear-end crashes.)

- Obstruction of driver vision was rarely a cited factor. (Little difference, LVS vs. LVM).

TABLE 4-1
RELATION TO JUNCTION BY REAR-END ACCIDENT SUBTYPE

Accident Type	Subtype (and Percent of Total)	Junction* (Row Percentage)	Non-Junction (Row Percentage)
Lead Vehicle Stopped	**Turning Left** 6.7%	91.2%	7.9%
	Going Straight 60.7%	59.6%	39.7%
	Turning Right 2.3%	80.0%	2.0%
Lead Vehicle Moving (Slower)	**Turning Left** 2.1%	91.7%	6.1%
	Going Straight 12.5%	35.9%	63.6%
	Turning Right 1.6%	91.5%	5.9%
Lead Vehicle Moving (Decelerating)	**Turning Left** 0.9%	89.9%	5.9%
	Going Straight 12.5%	35.0%	64.8%
	Turning Right 0.7%	83.8%	16.2%

* Includes Intersection, Intersection-Related, Interchange, Driveway/Alley, and Entrance/Exit Ramp.

Note: Row percentages do not add to 100% because rail grade crossings and "other" are excluded.

- To further illustrate the generally low involvement of environmental or driver impairment factors in these crashes, a retrieval was performed that identified LVS crashes that occurred on roadways that were not coded as curved, hilly, icy, or snow-covered; *and* did not occur under dark (unlighted) light conditions or adverse atmospheric conditions (e.g., rain, sleet, snow, fog, or combinations); *and* did not involve driver impairment in the striking vehicle (i.e., alcohol or drug use charged, other known physical impairment); *and* did not involve a known obscuring of driver vision (in the striking vehicle). In the 1990 GES, 51.1 percent of LVS crashes met all of these criteria; i.e. , involved none of the above environmental or driver factors.

- Rear-end crash involvement rate was found to vary significantly for different driver age and sex groups. Moreover, the distributions were somewhat different for the striking and struck vehicle roles. Rear-end crash involvement rates both for striking and struck vehicle roles (LVS and LVM combined) were based on driving mileage estimated for each age-sex group (Pisarski, 1992). Figure 4-10 shows the 1990 pattern for crash involvement rates by age group for men and women. For both striking and struck vehicle roles, the highest involvement rates were found for drivers aged 15 to 19. For the striking vehicle role, male and female drivers alike, crash involvement rates decreased as age increased up to age group 55-64, and then slightly increased for older drivers (age 65 and older). For the struck vehicle role, crash involvement rates also sharply decreased between age groups 15-19 and 20-24, but unlike the pattern seen in the striking vehicle role, the rates didn't vary as greatly across age groups above age 25. Male and female drivers showed a different crash involvement rate pattern for the two vehicle roles. 'Overall, female drivers had higher involvement rate than males as the struck vehicle driver, whereas the involvement rates as the striking vehicle driver were approximately equal for males and females.

  For all age groups combined, the crash involvement rates were:

  <u>Striking vehicle role</u>
  Male driver: 61.4 per 100 million VMT
  Female driver: 61.5 per 100 million VMT

  <u>Struck vehicle role</u>
  Male driver: 62.8 per 100 million VMT
  Female driver: 86.9 per 100 million VMT.

  (Note: The struck vehicles included any vehicle in which the vehicle role was coded as either "struck" or "both striking and struck." Therefore the the overall crash involvement rate here for struck vehicle driver is higher than the overall rate for striking vehicle driver.)

FIGURE 4-1: TIME OF DAY

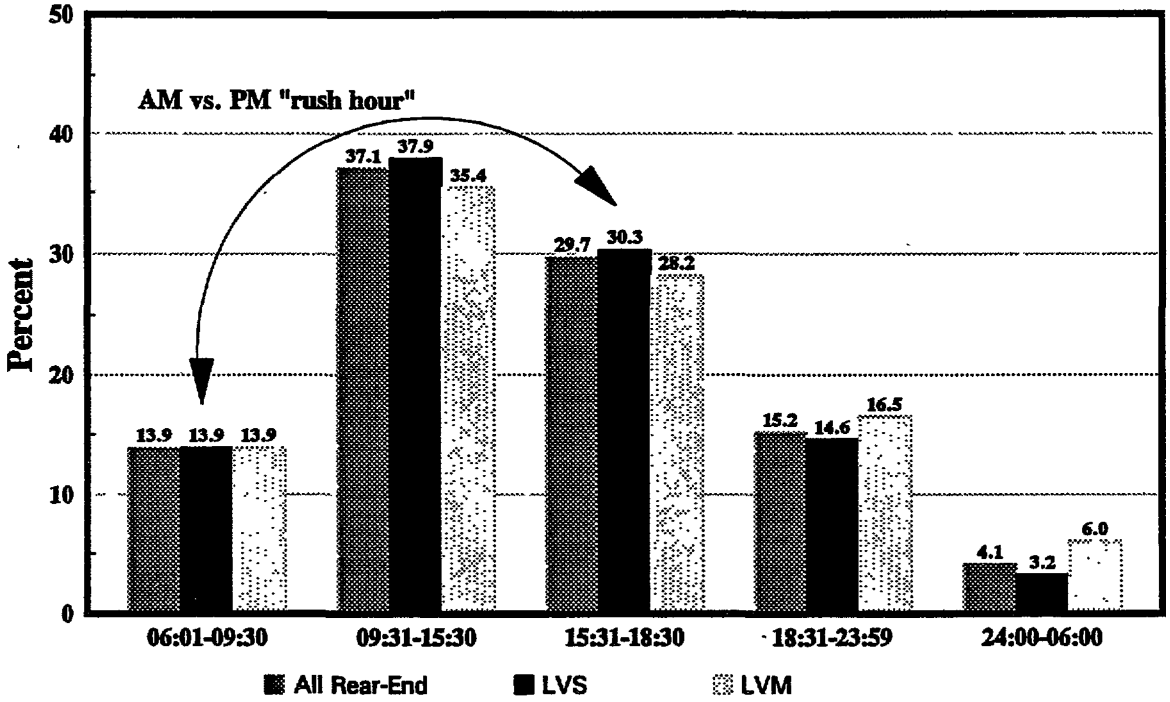


FIGURE 4-2: LAND USE (POPULATION)

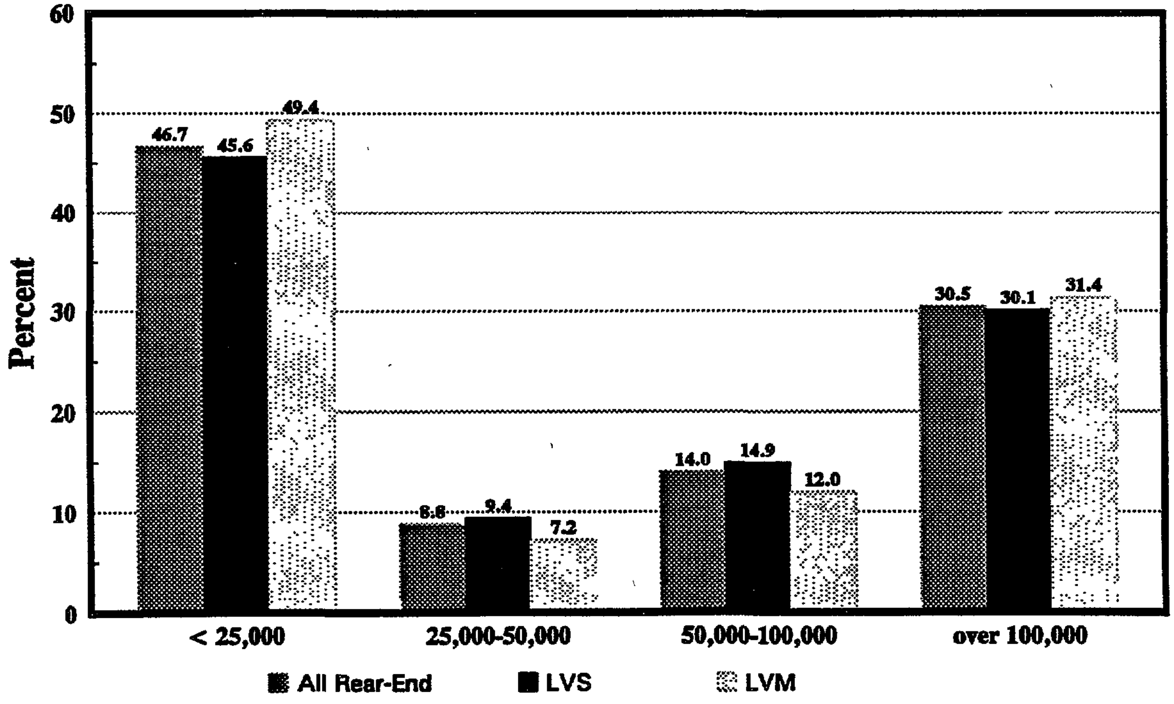


FIGURE 4-3: MOST COMMON RELATION TO JUNCTION

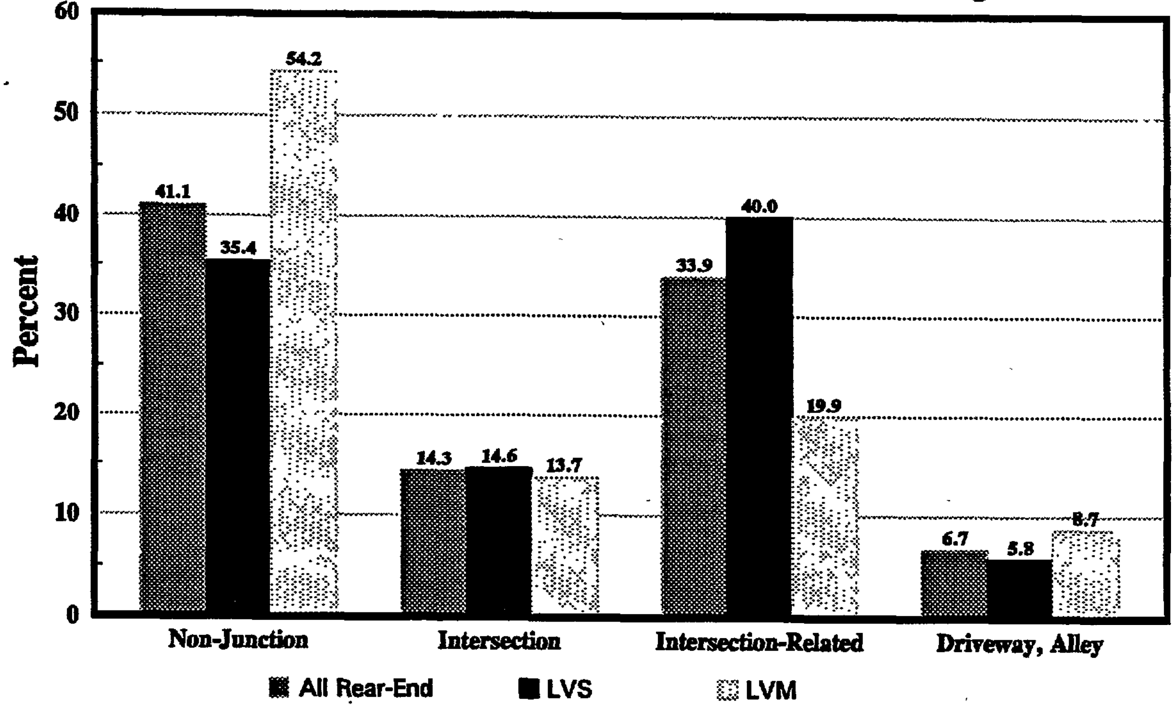


FIGURE 4-4: TRAFFICWAY FLOW

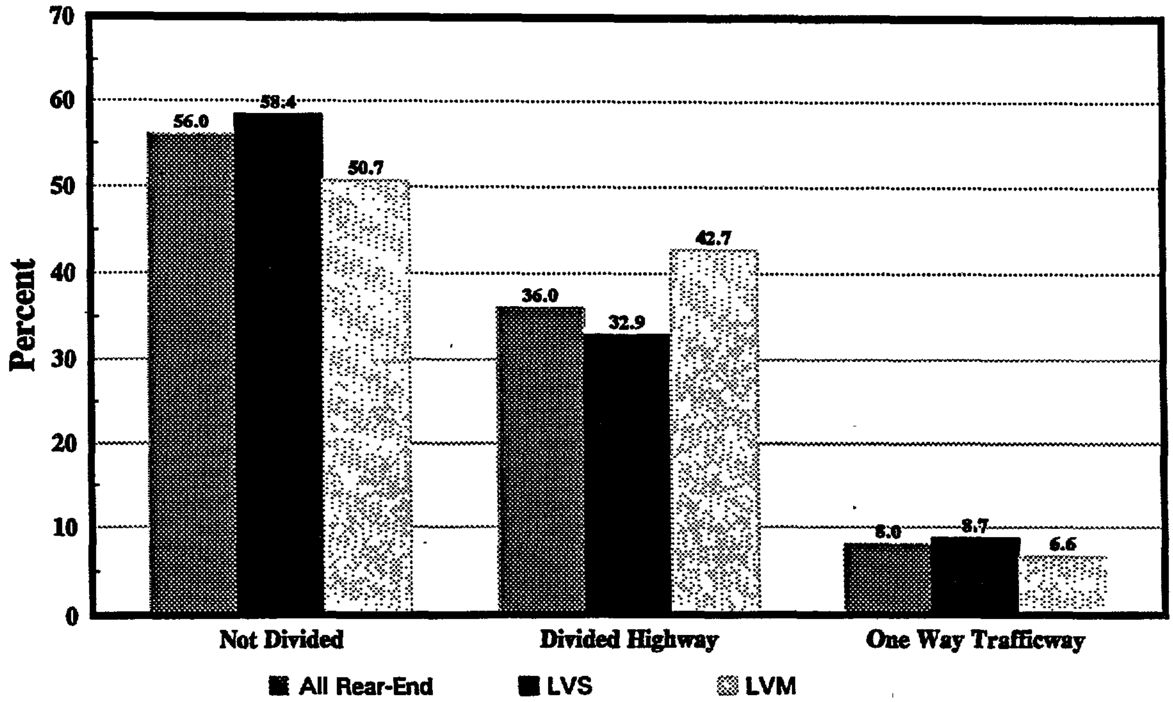


FIGURE 4-5: MOST COMMOND ROADWAY PROFILE

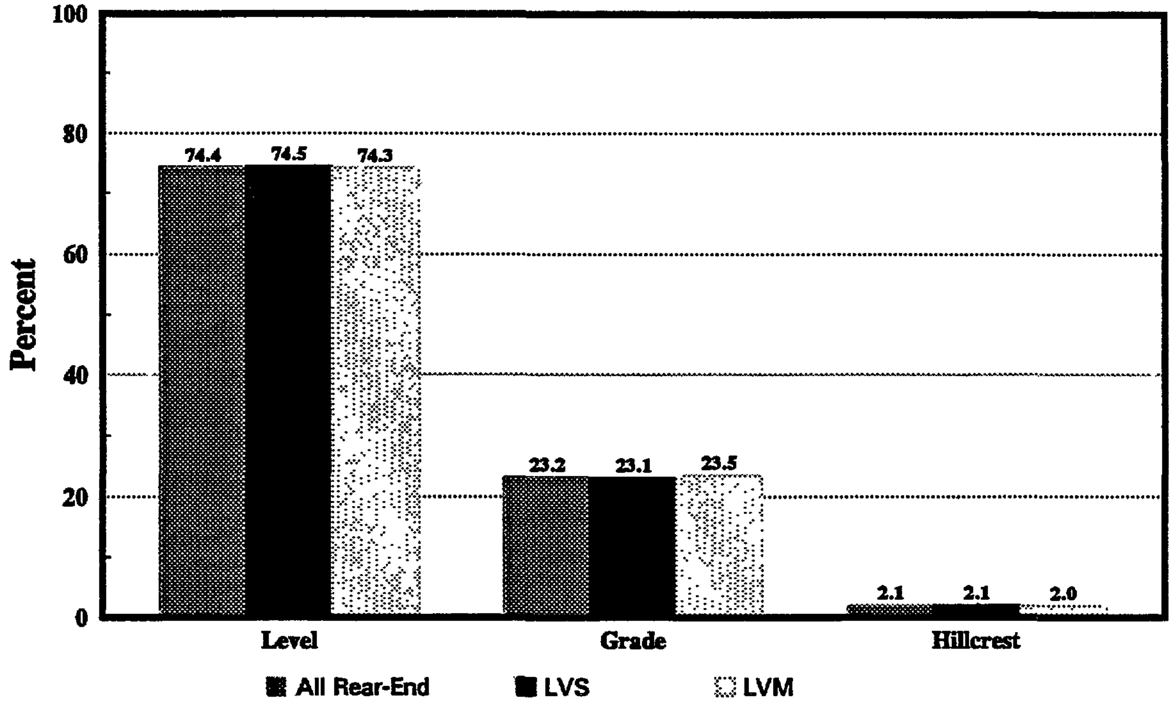


FIGURE 4-6: ROADWAY SURFACE CONDITION

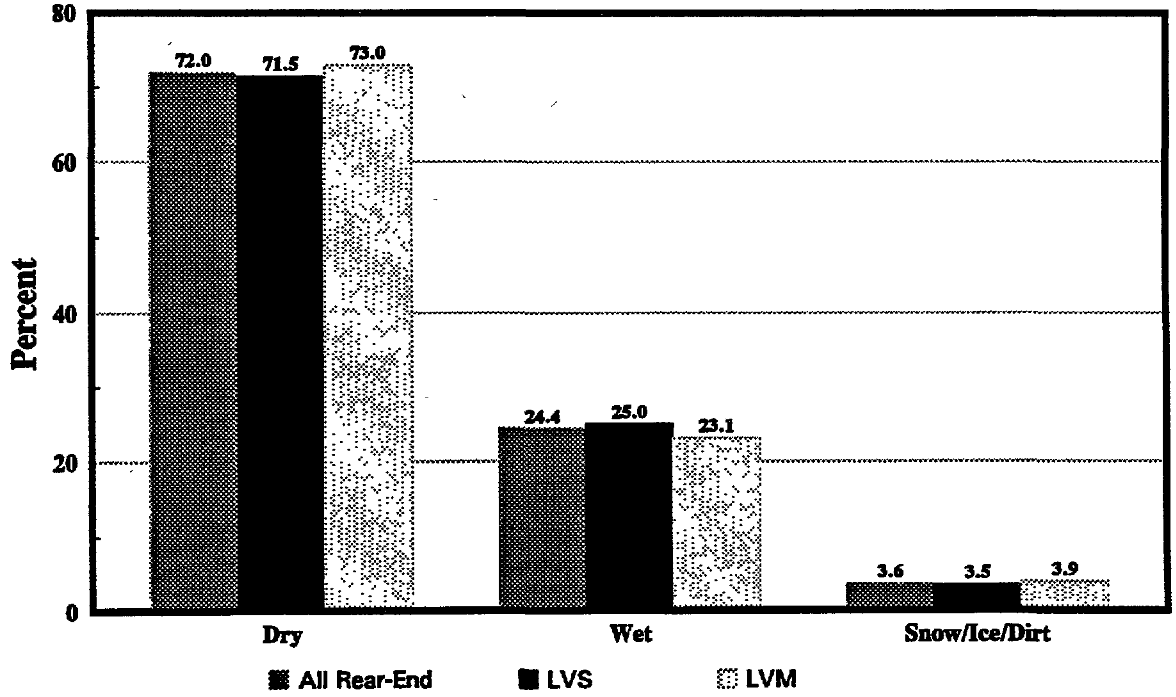


FIGURE 4-7: SPEED LIMIT

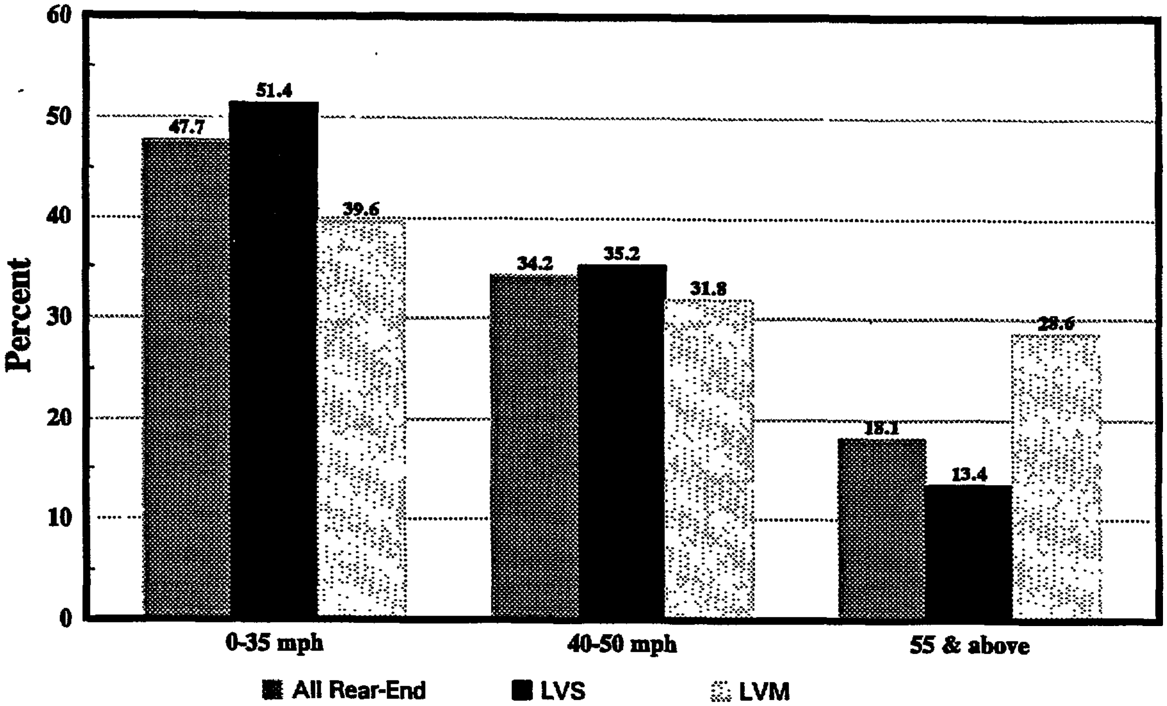


FIGURE 4-8: LEAD VEHICLE ACTION/INTENTION

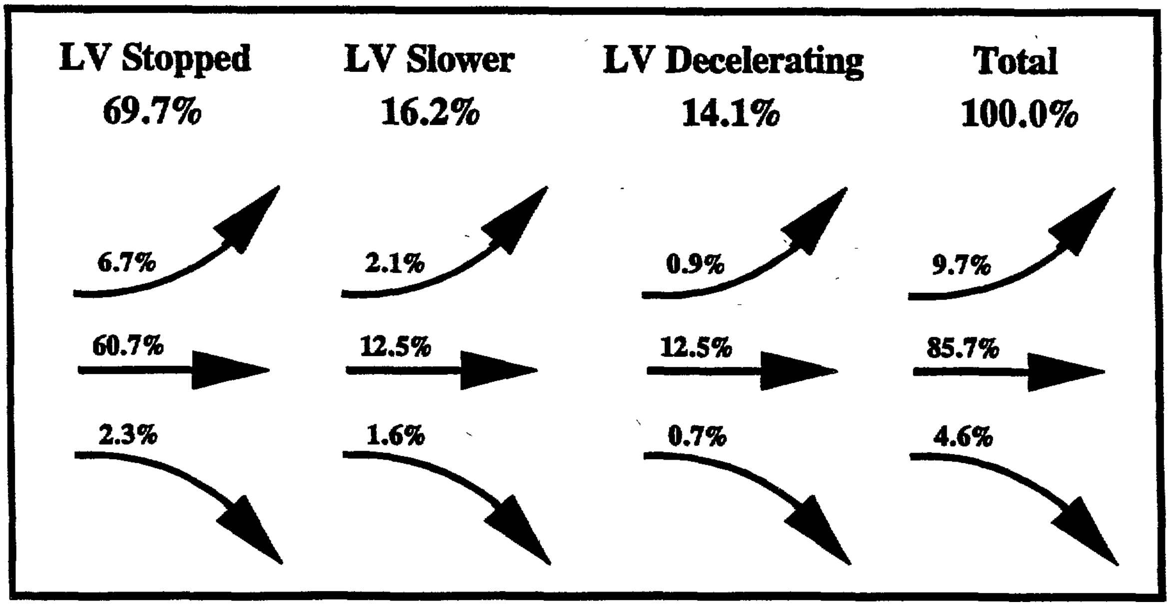


FIGURE 4-9: MOST COMMON VIOLATION CHARGED

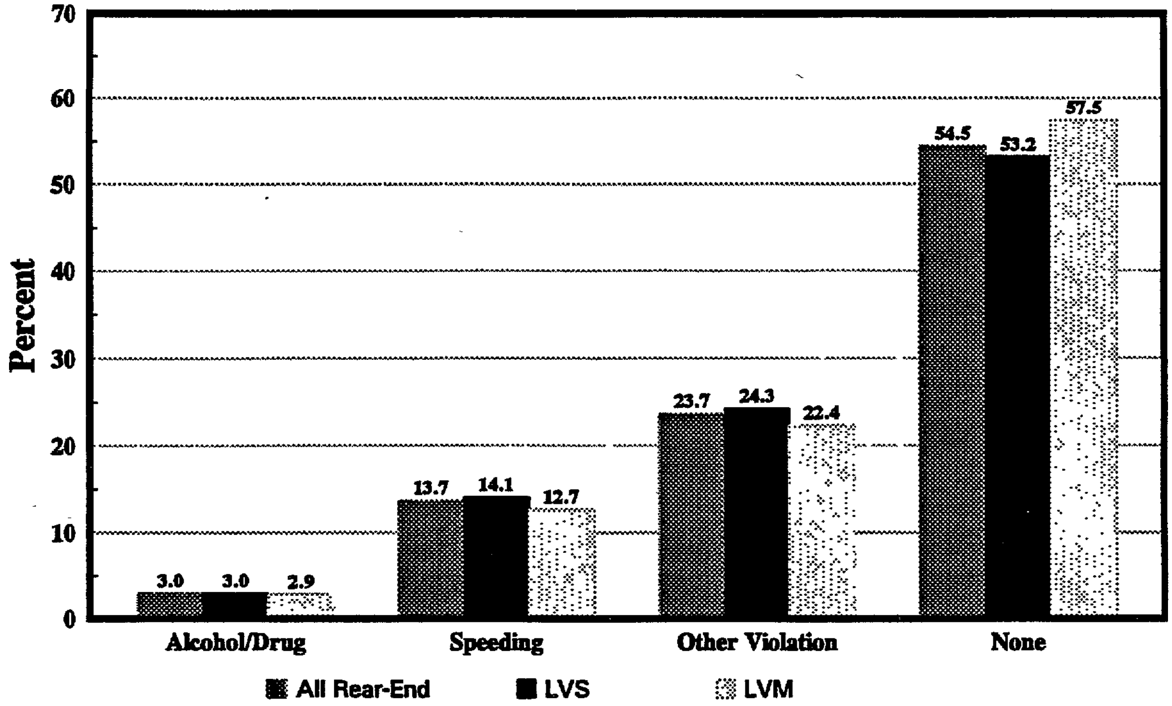
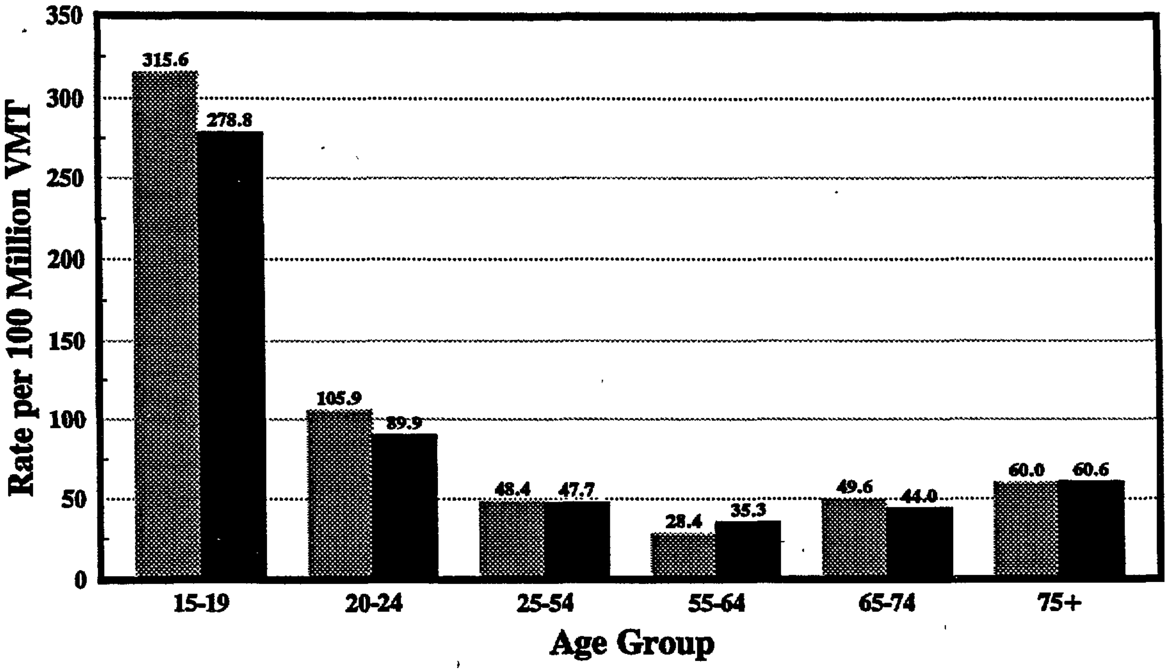
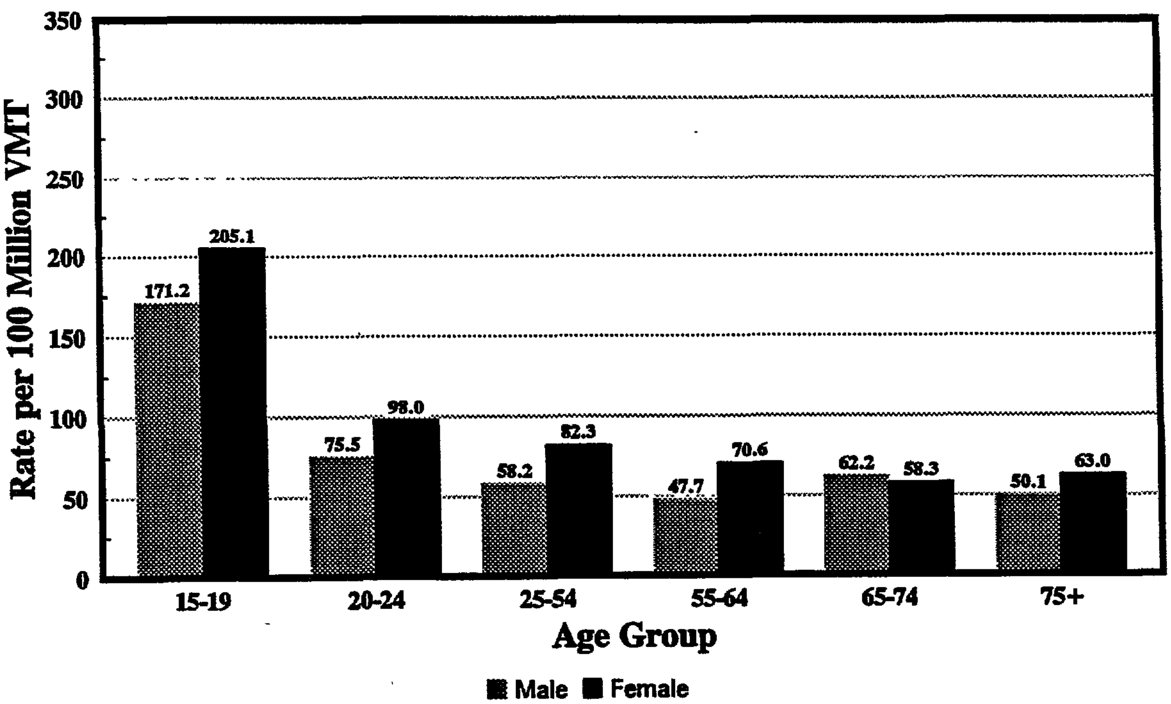


FIGURE 4-10: CRASH INVOLVEMENT RATE BY DRIVER'S AGE AND SEX

STRIKING VEHICLES



STRUCK VEHICLES



5. TRI-LEVEL STATISTICS ON CRASH CAUSES

Indiana Tii-Level study (Treat et al, 1979 a; see section A.1.5 of Appendix A of this report) findings on the causal factors associated with 45 rear-end, lead vehicle stationary (CARDfile Accident Type 203), and 12 rear-end, lead-vehicle-moving crashes (CARDfile Accident Types 205,207, 209) were accessed. It is notable that the high proportion of LVS crashes (45 of 57; 79 percent) is consistent with the high proportion of stopped struck vehicles found in GES.

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 53 of the 57 cases (93 percent). Recognition errors are most frequently cited (45 cases; 79 percent).

At more detailed levels, the causal factors listed below are notable. Statistics are presented separately for LVS and LVM crashes. Generally, only those factors cited in 10 percent or more of the cases in each category are listed, although some lower-frequency factors are included in the lists for completeness. The indentation reflects the Tri-Level taxonomy of crash causes.

Rear-End, Lead Vehicle Stationary (LVS; 45 cases):

- **Vehicular factors (5 cases, 11%)**
- **Human causes (42 cases, 93%)**

    Direct human causes (42 cases, 93%)

        Recognition errors (37 cases, 82%)
            Recognition delays -- reasons identified (31 cases, 69%)
                Inattention (19 cases; 42%)
                    Traffic stopped or slowing (15 cases; 33%)
                    Due to event in car (e.g., sudden noise) (6 cases; 13%)
                Internal distraction (2 cases,, 4%)
                External distraction (5 cases; 11%)

        Decision errors (11 cases, 24%)

    Indirect human causes (e.g., alcohol, drugs) (4 cases, 9%)

- **Environmental causes (e.g., slick roads, view obstructions) (4 cases, 9%).**

Rear-End, Lead Vehicle Moving (LVM; 12 cases total):

- **Vehicular factors (2 cases, 17%)**
  Brake system (2 cases, 17%)

- **Human causes (11 cases, 92%)**

  Direct human causes (11 cases, 92%)

  Recognition errors (8 cases, 67%)
  Recognition delays -- reasons identified (8 cases; 67%)
  Inattention (3 cases; 25%)
  Traffic stopped or slowing (3 cases; 25%)
  Due to event in car (e.g., sudden noise) (2 cases; 17%)
  External distraction (4 cases; 33%)

  Decision errors (6 cases, 50%)
  False assumption (e.g., assumed car was turning, did not) (5 cases, 42%)

- **Environmental causes (e.g., slick roads, view obstructions) (2 cases, 17%).**

In short, the Tri-Level statistics portray rear-end crashes as resulting largely from inattention and other forms of delayed recognition, with little involvement of vehicle factors, indirect human causes (e.g., alcohol), or environmental factors. This pattern is true for both LVS and LVM crash subtypes, but is especially true for the LVS crashes, which constitute the majority of the Indiana Tri-Level rear-end sample.

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 Data files and Other Information Sources Accessed

The following data sources have been used to estimate rear-end and "all crashes" problem size and descriptive statistics:

A.l.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 45,000 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 1988, 1989, 1990 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 coroners' reports on blood alcohol content when available. 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.

A.1.4 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., enviromnental conditions, collision scenarios). (Note, however, that CDS has added new variables on pre-crash events beginning with the 1992 data collection year).

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 limited (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 sixes, 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 1990 (FHWA-PL91-003). Table VM-1 (Page 192) 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 Site

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 'combination-unit truck striking rear-end crashes", the combination-unit truck was striking, but 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 rear-end 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. Statistics for medium-heavy single-unit trucks, motorcycles, and/or automobile vs. light truck/van breakouts may be provided if warranted by the crash type. 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 crushes*
- **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 rear-end crashes, the estimate is from the 1990 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 rear-end 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 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"**
  - **No Injury (0); includes other unknowns**

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

Explanation: For rear-end crashes, injuries are assessed based on GES data. Totals include all non-fatal injuries (i.e., A+B+C 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 1.

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 theii 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 crash severity is used to determine total FCEs for all crashes and for all crash types.

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 (O,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, rear-end 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 — ***Calculated from target PR crashes*** **Traveled 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., striking vehicle in a rear-end 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 rear-end 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 not 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: 1989 AND 1990 VEHICLE MILES TRAVELED (IN MILLIONS) FOR VARIOUS VEHICLE CATEGORIES
(Source: *Highway* Statistics, *1990,* FHWA, Table VM-1)

ANNUAL VEHICLE MILES TRAVELED (VMT, in millions)		
Vehicle Category:	1989	1990
All Vehicle Types	**2,107,040**	**2,147,501**
Passenger Vehicles	**1,942,173**	**1,982,197**
Combination-Unit Trucks	**95,567**	**96,482**
Single-Unit Trucks	**53,190**	**53,522**

Average annual miles traveled per vehicle in 1990 were as follows for these four vehicle type categories:

- All vehicle types: 11,132 miles
- Passenger vehicles: 10,879 miles
- Combination-unit trucks: 60,032 miles
- Single-unit trucks: 12,683 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 rear-end crashes) or based upon a particular vehicle role in the crash (e.g., struck vehicle in rear-end 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 2-axle, 4-tire trucks and thus'corresponds to the "Other Single-Unit Trucks' column of Table VM-1 of Highway *Statistics.*

TABLE A-3: 1989 AND 1990 VEHICLE REGISTRATIONS FOR VARIOUS VEHICLE CATEGORIES (Source: *Highway* Statistics, 1990, FHWA, Table VM-1)

VEHICLE REGISTRATIONS		
Vehicle Category:	1989	1990
All Vehicle Types	191,694,462	192,914,924
Passenger Vehicles	185,366,849	182,201,372
Combination-Unit Trucks	1,589,285	1,607,183
Single-Unit Trucks	4,102,863	4,219,920

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 approximated by the following formula:

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

Life the previous two statistics, this statistic may be calculated based on all involvements (e.g., all crashes, all rear-end crashes) or based upon a particular vehicle role in the crash (e.g., struck vehicle in rear-end 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 (Miaou, 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:

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

Statistical constants used to make these calculations include the following:

- All NPR crashes, all vehicle types: 7.77 million (Miier, 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 Miier, 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 from datafile*
- **NPR**	*Estimated based on PR UDH target crashes*
• **Non-Urban Divided Highway**	*Total PR + NPR*
- **PR**	*Accessed 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).

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 460.2 million vehicle hours for 1990).***

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 460.2 million vehicle-hours for 1990. 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 huger 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 A.2 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 rear-end 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 1990 GES, for example, these totaled 6.4 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 (V5I, 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</= Body Type < /=49

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

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

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

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

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

01</= Body Type </= 14, or
40 < /=Body Type </=69

FARS Combination-Unit Truck:

Body Type = 70 (single-unit straight truck, GVWR 10,000-19,500 & 1</= TOW_VEH </= 4
Body Type = 71 (single-unit straight truck, GVWR 19,500-26,000 & 1</= TOW_VEH </=4
Body Type = 72 (single-unit straight truck, GVWR over 26,000) & 1</= TOW_VEH </=4
Body Type = 74 (truck-tractor; cab only or any number of trailers)
Body Type = 75 (unknown medium truck) & 1</=TOW-VEH </=4
Body Type = 76 (unknown heavy truck) & TOW_VEH > 0
Body Type = 78 (single-unit straight truck, GVWR unknown) & 1< /=TOW_VEH </=4
Body Type = 79 (unknown truck type) & 1</=TOW_VEH</= 4

FARS Single-Unit Truck:

Body Type = 70 (single-unit straight truck, GVWR 10,000-19,500) & TOW_VEH = 0 or 9
Body Type = 71 (single-unit straight truck, GVWR 19,500-26,000) & TOW_VEH = 0 or 9
Body Type = 72 (single-unit straight truck, GVWR over 26,000) & TOW_VEH = 0 or 9
Body Type = 75 (unknown medium truck) & TOW-VEH = 0 or 9
Body Type = 76 (unknown heavy truck) & TOW-VEH = 0
.Body Type = 78 (single-unit straight truck, GVWR unknown) & TOW-VEH = 0 or 9

APPENDIX B: PROBLEM SIZE ASSESSMENT: ALL CRASHES

This appendix presents crash problem size assessment statistics for the "universe" of crashes. Primary estimates are provided based largely on 1990 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 1989 and 1990 statistical findings and associated estimates derived as described in Appendix A. Table B-l indicates that, overall police-reported crashes, fatalities and non-fatal injuries decreased between 1989 and 1990. However, urban-divided highway crashes (per the GES "Percent Rural" variable) increased in 1990. **Table B-l** also reveals that even though police-reported crashes and fatalities experienced a decrease in 1990, the estimated crash-caused hours of delay were greater in 1990 (The difference is about 18 million hours). **Table B-2** provides more detailed 1990 statistics for all vehicles, passenger vehicles, and combination-unit trucks.

Standard errors of estimate for 1990 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	1989	1990
Police-Reported Crashes (GES)	**6.64 million**	**6.46 million**
Vehicles Involved in Police-Reported Crashes (GES)	**11,556,000**	**11,315,000**
Fatalities (FARS)	**45,582**	**44,599**
Non-Fatal Injuries in PR Crashes (GES)	**3.28 million**	**3.23 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)	**2.11 million**	**2.23 million**
Crash-Caused Vehicle-Hours Delay	**442.0 million hours**	**460.2 million hours**

* Same estimate used for 1989 and 1990 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 rear-end crashes, involvement statistics are based on subject vehicle (e.g., striking vehicle) involvements only. For any crash type, the subject vehicleis 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 1990, Combination-unit truck had a crash involvement ***rate*** (per 100 million vehicle miles traveled) that was 45 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 274 percent of the passenger vehicle likelihood.

TABLE B-2
PROBLEM SIZE ESTIMATE: ALL CRASHES
INVOLVED VEHICLE TYPES: ALL VEHICLES, PASSENGER VEHICLES, COMBINATION-UNIT TRUCKS

GES/FARS-Based Statistics (1990)

		All Vehicles	Passenger Vehicles	Combination-Unit Trucks
Annual # PR Crashes (GES)	Total:	6,462,000	6,299,000	223,000
	Injury:	2,153,000	2,092,000	62,000
	PDO:	4,309,000	4,207,000	161,000
Annual # Fatalities (FARS)		44,599	40,829	4,217
Ann. # Non-Fatal PR Injuries (GES)	Total:	3,231,000	3,144,000	85,000
	A:	478,000	457,000	16,000
	B:	942,000	908,000	24,000
	C:	1,812,000	1,779,000	46,000
Fatal Crash Equivalents (FCEs)		89,907	86,203	4,883
Involvement Rate Per 100 Million VMT		526.9	542.3	237.9
Annual Involvements Per 1,000 Vehicles		58.65	58.99	142.83
Expected # Involvements During Vehicle Life		0.7701	0.7675	2.0996
Estimated Annual # NPR Crashes	Total:	7,770,000	7,586,000	291,000
	Injury:	917,000	895,000	34,000
	PDO:	6,853,000	6,691,000	256,000
Estimated Total Annual Crashes (PR + NPR)	Total:	14,232,000	13,885,000	514,000
	UDH:	2,235,000	2,188,000	155,000
	Non-UDH:	11,997,000	11,696,000	359,000
Crash-Caused Congestion (Delay)	Veh-Hours:	460.2 M	450.3 M	29.8 M

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

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 1990 there were approximately 18.9 fatalities per 1,000 police-reported truck crashes, versus approximately 6.5 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-1). The value of 89,907 FCEs shown in Table B-2 for all vehicles was derived from statistics on 1990 GES crash severity (fatal and various levels of non-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)	30,760	1.0000	30,760
Incapacitating (A, 3)	359,491	0.0840	30,197
Non-incapacitating (B, 2)	666,337	0.0178	11,861
Possible Injury (C, 1)	1,096,092	0.0093	10,194
No injury (0, 0)	4,309,446	0.0016	6,895
All Crashes, All Vehicles	6,462,126		**89,907**

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 1990 GES

This appendix presents tables for estimating sampling errors for 1990 GES estimates. These tables (and the narrative explanation below) are taken from the "Technical Note for 1988, 1989, 1990 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 45,000 motor vehicle police traffic accident reports selected on an annual basis. GES is *not* a census of all 6.5 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-1:

1990 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

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

a=9.93401

6=0.06362

TABLE C-2:

1990 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

$$*SE=e^{\frac{a}{2}+\frac{b}{2}[\ln(x)]^2}\text{, where}$$
$$a=8.83524$$
$$b=0.06977$$

TABLE C-3:

1990 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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