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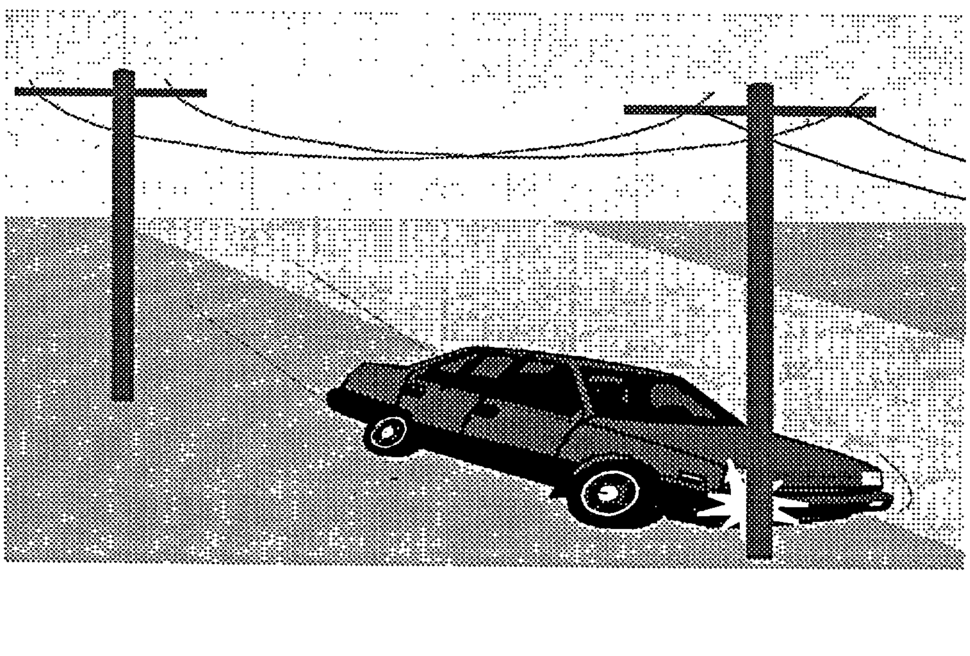
Single-Vehicle Roadway Departure Crashes: Problem Size Assessment and Statistical Description



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16. Abstract

This document presents problem size assessments and statistical crash descriptions for single vehicle roadway departure (SVRD) crashes. SVRD crashes, associated with more fatalities than any other accident type, are a major "target crash" of high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. Principal data sources are the 1991 General Estimates System (GES) and Fatal Accident Reporting System (FARS). The SVRD 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 five vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans), combination-unit trucks, medium/heavy single-unit trucks and motorcycles. SVRD crashes are described statistically primarily in terms of the conditions under which they occur (e.g., time of day, weather, roadway type, relation to junction) and, when data are available, in terms of possible contributing factors.

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EXECUTIVE SUMMARY

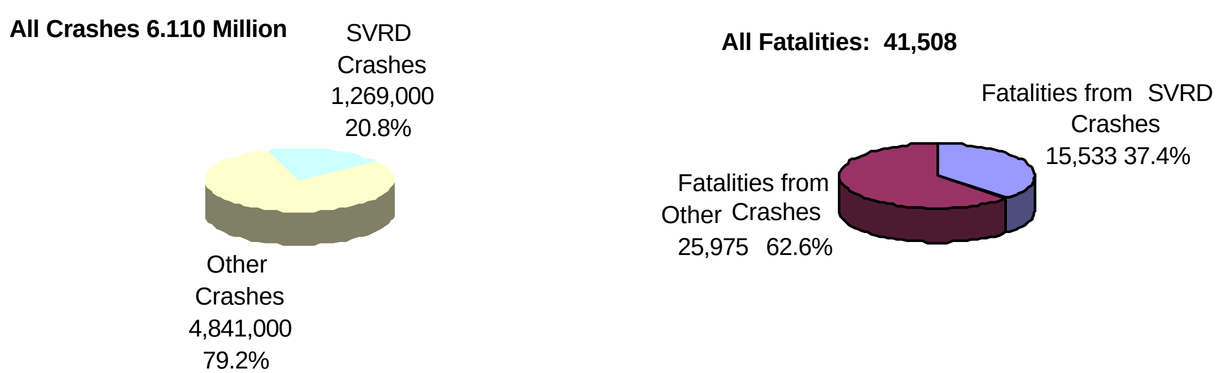
This document presents problem size assessments and statistical crash descriptions for single vehicle roadway departure (SVRD) crashes, including crashes into parked vehicles. Principal data sources are the 1991 General Estimates System (GES) and Fatal Accident Reporting System (FARS). SVRD crashes are potential “target crashes” of various conventional and high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. For example, a “lateral detection” system has been suggested as an applicable countermeasure to some SVRD crashes. Such a system would monitor the vehicle’s lateral position within the travel lane and detect imminent roadway departures. In this report, the SVRD 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 five vehicle type categories: all vehicles combined, passenger vehicles (i.e., cars, light trucks, light vans), combination-unit trucks, medium/heavy single-unit trucks, and motorcycles.

Overall Problem Size

Principal statistical findings regarding the SVRD crash problem size include’ the following:

> In 1991, there were approximately 1,269,000 police-reported SVRD crashes with 15,533 associated fatalities. **Figure ES-l** illustrates SVRD crash and fatality statistics in relation to all crashes and crash fatalities. Figure ES-1 shows that SVRD crashes constituted about 20.8 percent of all police-reported crashes and accounted for about 37.4 percent of all motor vehicle crash fatalities in 1991.

FIGURE ES-1



- There were approximately 574,000 associated injuries, including 121,000 serious (incapacitating) injuries.
- Nevertheless, approximately 65.2 percent of 1991 SVRD crashes were property-damage-only.
- During its operational life, a vehicle can be expected to be involved in 0.09 police-reported (PR) SVRD crashes.
- The above statistics relate to police-reported crashes. This report presents a method for estimating ***annual non-police reported*** (NPR) SVRD crashes, which yielded an estimate of approximately 1,580,000 for 1991.
- The report also presents a method for estimating crash-caused delay in vehicle-hours. Based on the estimation algorithm described in the report, SVRD crashes cause about 16.5 percent of all crash-caused delay.

Vehicle Type Comparisons

The above statistics relate to all vehicle types combined. The report presents problem size statistics on SVRD crashes for several major vehicle type categories, including passenger vehicles (here defmed as cars, utility vehicles, light trucks, and vans), combination-unit trucks (Le., tractor-trailers), single-unit medium/heavy trucks and motorcycles. In 1991, SVRD crashes constituted 20.1 percent of passenger vehicle crashes, 13.5 percent of combination-unit crashes, 12.4 percent of single-unit truck crashes and 18.2 percent of motorcycle crashes.

Not surprisingly, the vast majority of these crashes (95 percent) involve passenger vehicles. However, motorcycles have a crash involvement rate per 100 million VMT that is about four times higher than that of passenger vehicles. Combination-unit trucks have a low ***rate*** of involvement, but, due to their high mileage exposure and long operational life, have the highest ***likelihood*** of involvement over vehicle life.

Motorcycle SVRD crashes were about five times more likely to be fatal than were those of other vehicle types.

Crash Characteristics

Descriptive statistics are provided for SVRD and fatal SVRD crashes. There were some notable statistical differences between all SVRD crashes and fatal SVRD crashes. SVRD crashes frequently occurred between 9:31 A.M. and 3:00 P.M., while fatal SVRD crashes' more often occurred between midnight (12:00 P.M.) and 6:00 A.M.. Compared to all SVRD crashes, fatal SVRD crashes are more likely to occur on 55-65 mph roadways and under dry roadway surface conditions. In addition, they are nearly three times more likely to involve alcohol.

Comparisons between the passenger vehicles and combination-unit trucks are also provided. Some statistical differences across vehicle types are apparent, even though crashes involving all vehicle types occurred largely during daytime hours With no adverse weather conditions or other major environmental contributing factors.

Driver age and sex involvement patterns were calculated using two different statistical metrics: rate (per 100 million VMT) and likelihood (involvements per 1,000 registered drivers). Unlike other descriptive statistics, the age/sex statistics were calculated for 1990 rather than 1991. Involvement rates per 100 million VMT were highest for younger drivers and lowest for middle-aged drivers. Compared to middle-aged and older drivers, younger drivers showed a greater difference in crash involvement rate between male and female drivers. Overall, males had a higher involvement rate (68.5 per 100 million vehicle miles traveled) than did females (52.1 per 100 million VMT).

The SVRD crash involvement likelihood (involvements per 1,000 licensed drivers) pattern is similar to that based on the VMT. The likelihood of involvement generally decreased with advancing driver age. There were 36 SVRD, crash involvements per 1,000 teenaged drivers, compared to less than 5 SVRD crash involvements per 1,000 licensed drivers aged 55 and older. Overall, the likelihood of involvement for male drivers was twice that of female drivers (10.0 SVRD crash involvements/per 1,000 male drivers to 4.7 SVRD crash involvements per 1,000 female drivers).

Alcohol involvements comprised 18.6 percent of passenger vehicle SVRD crashes (as recorded on the police accident report), compared to only 1.0 percent of combination-unit truck target crashes. For fatal SVRD crashes, 60.1 percent involved alcohol. About 68.6 percent of fatal SVRD motorcycle crashes involved alcohol, versus 60.8 percent of fatal SVRD passenger vehicle crashes and 16.7 percent alcohol involvement for fatal combination-unit truck SVRD crashes. Thus, the role of alcohol involvement in fatal motorcycle SVRD crashes is greater than that for passenger vehicles or combination-unit trucks.

The most common violations charged were alcohol/drugs, speeding, and reckless driving, although alcohol/drug violations were rare) for combination-unit truck drivers. Driving too fast was by far the most frequently-cited driver factor in, fatal SVRD crashes - it was cited in just over half (50.5 percent) of such crashes.

Information on driver alertness and other physical impairments is also provided for both SVRD and fatal SVRD crashes. Overall, 4.4 percent of SVRD drivers were cited as drowsy or sleepy. The percentage for combination-unit truck drivers (6.2 percent) was somewhat higher than that for passenger vehicle drivers (4.5 percent). Drowsiness was more frequently cited in fatal SVRD crashes, where the percentage was twice as high for combination-unit trucks (15.2 percent) as for passenger vehicles (7.3 percent).

Data from the Indiana Tri-Level study (Treat ***et al,*** 1979) were accessed to provide information on the causes of SVRD crashes. One hundred f&y-three (153) cases were identified. The Tri-Level statistics portray SVRD crashes as resulting largely from driver decision errors (e.g., excessive speed, improper evasive action) and recognition errors (e.g., recognition delay, inattention, and improper lookout).

<u>Appendices</u>

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

1. INTRODUCTION

This document presents problem size assessments and statistical crash descriptions for single vehicle roadway departure (SVRD) crashes, including crashes into parked vehicles, SVRD crashes are major "target crashes" of various conventional and high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. Indeed, more fatalities are associated with SVRD crashes than any other crash type. In this report, the SVRD 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). SVRD 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 document provides statistics on current SVRD crash problem size and statistics describing the conditions of occurrence and, to a limited extent, the causes of SVRD crashes. Most statistics provided are estimates based on national crash databases, such as the 1991 NHTSA General Estimates System (GES). Applicable crash fatality counts from the 1991 Fatal Accident Reporting System (FARS) are also presented (Note: see Appendix A for more detailed description of GES and FARS). Both GES and FARS statistics address only ***police-reported*** crashes, although a rough estimate of the non-police-reported SVRD crash population is provided in this report based on a new estimation procedure for these crashes.

This problem size assessment and statistical description of SVRD 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 SVRD crashes. This related analytical modeling work is described in a technical report by Hendricks et ***al*** (1993). Several countermeasure concepts are examined by Hendricks, including an in-vehicle lateral proximity detection system that would be intended to detect dangerous deviations in lateral lane position.

The-crash problem statistics presented in this report are intended to be compatible with the above and other ongoing causal analyses and countermeasure modeling efforts. This information supports the assessment of potential safety benefits of crash prevention approaches and also helps to define the conditions under which the countermeasure must operate in order to be effective.

The remainder of this report is organized as follows:

- Chapter 2 defines SVRD crashes (per major accident database) and presents data on SVRD crash problem size.

- Chapter 3 provides descriptive statistics regarding all SVRD crashes and fatal SVRD crashes. This also includes crash and fatal crash involvement rates for various driver age and sex groups

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

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

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

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

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

2 . SVRD CRASH PROBLEM SIZE

This chapter presents overall problem size assessment for single vehicle roadway departure (SVRD) crashes and a larger "universe" of single vehicle (SV) crashes. SV crashes, obtained from 1991 GES, can be categorized into four configurations: right roadway departure, left roadway departure, forward impact (including collisions with parked vehicles), and backing crashes. A list of specification for these four configurations are listed below. In addition to single driver involved (VEH_INVL = l), GES variable accident type (ACC_TYPE) was also used to derive an appropriate SV crash size.

Right or left roadwav departure

- Drive off road (ACT-TYPE = 01 and 06) - a vehicle departed the road under controlled situation.
- Control/Traction Loss (ACT-TYPE = 02 and 07) - a vehicle lost traction or in some other manner "got away" from the driver.
- Avoid collision with vehicle, pedestrian, animals (ACT-TYPE = 03 and 08) - a vehicle departed the road as a result of avoiding something on the road.
- Specific other or unknown (ACT-TYPE = 04, 05, 09 and 10).

Forward impact

- Forward impact to parked vehicle (ACT-TYPE = 11).
- Forward impact to stationary object (ACT-TYPE = 12).
- Forward impact to pedestrian/animal (ACT-TYPE = 13).
- Forward impact, end departure (ACT-TYPE = 14) - a vehicle moving forward and over the end of road.

Backing

- Backing (ACT_TYPE = 92).

In 1991, there were appoximately 1,769,OOO SV crashes, of which 1,269,OOO are here classified "SVRD." **Table 2-l** shows the numeric distribution of all SV crashes by configuration, accident type and the roadway location of the first harmful event. All crash statistics are rounded to the nearest 1,000.

TABLE 2-1. SINGLE VEHICLE CRASHES

Accident Type		On Roadway	Off Roadway/Shoulder	Other & Unknown
Right Roadway Departure	Drive Off Road	N/A	283,000	1,000
	Control/Traction Loss	N/A	205,000	0
	Avoid Collision With Veh, Ped/cyclist, Animal	N/A	56,000	0
	Specifics Other or unknown	N/A	6,000	0
Left Roadway Departure	Drive Off Road	N/A	148,000	0
	Control/Traction Loss	N/A	186,000	1,000
	Avoid Collision With Veh, Ped/cyclist, Animal.	N/A	34,000	0
	Specific Other or Unknown	N/A	4,000	0
Forward Impact	Forward Impact ro Parked Vehicle	0	315,000	7,000
	Forward Impact to Stationary Object	29,000	5,000	1,000
	Forward Impact to Pedestrian/Animal	349,000	11,000	3,000
	Forward Impact, End Departure	0	26,000	0
	Specific Other or Unknown	6,000	2,000	0
Backing	Backing Vehicle	2,000	86,000	2,000

SVRD crashes: 1,269,000 (71.8%) Non-SVRD Single Vehicle Crashes: 499,000 (28.2%)

For the purpose of this report, SVRD crashes include all single vehicle crashes where the first harmful event occurred off the roadway, except for backing and pedestrian/animal related crashes. SVRD crashes indicated by the shaded area in Table 2-1, accounted for 71.8 percent of all single vehicle crashes. Approximately 40.2 percent of SVRD crashes were right side roadway departures, 27-3 percent were left side roadway departures, and 23.5 percent were “forward impacts”, (e.g.. impacts with parked vehicles.

Note that crashes in which a vehicle is backing and impacts to pedestrian/pedalcyclists are ***not*** addressed in this report. The backing crash scenario is addressed in a separate report (see Wang and Knipling, 1993).

2.1 Definition and Overall SVRD Problem Size

This section specifies target crash definitions and presents a summary of the overall SVRD problem size for several major vehicle types based on the 1991 GES and FARS.

The **1991** GES SVRD crash data is based on the following specification:

Number of Vehicles (A3, VEH_INVL) = 1

Accident Type (V23, ACC_TYPE)	= 01 - 05	(Right Roadway Departure)
	= 06 - 10	(Left Roadway Departure)
	= 11 - 12, 14 - 16	(Forward Impact)

Relation to Roadway (AlO, REL_RWY)	= 2 (On Shoulder/Parking Lane)
	= 3 (Off The Roadway/Shoulder/ Parking Lane)
	= 4 (On The Median)

1991 FARS SVRD fatal crash and fatality counts are based on the following criteria:

Vehicle Forms Submitted (VE_FORMS)	= 1
Vehicle Maneuver (VEH_MAN)	≠ 15 (Backing Up)
Relation to Roadway (REL_ROAD)	= 2 (Shoulder)
	= 3 (Median)
	= 4 (Roadside)
	= 5 (Outside Right-of-Way)
	= 6 (Off Roadway, Location Unknown)
	= 7 (In Parking Lane)
	= 8 (Gore)

Separate definitions were used for GES (SVRD crashes) and FARS (SVRD fatal crashes) because the 1991 FARS does not contain the Accident Type variable. A consistency check was performed by using the Vehicle Maneuver specification described for FARS in GES and then comparing with those obtained using the Accident Type specification. Recall from Table 2-1 that the Accident Type SVRD crash specification used for GES yielded an estimate of 1.269 million SVRD crashes for 1991. The Vehicle Maneuver SVRD crash definition applied to GES (the specific variable used was Imputed Vehicle Maneuver; MANEUV I) yielded an estimate of 1.370 million crashes. However, 29,000 of these were no-impact crashes. Excluding these no-impact crashes, the Vehicle Maneuver definition yielded a GES estimate of 1.341 million SVRD crashes, 5.7 percent more than the 1.269 million estimate based on the Accident Type specification. Since the two definitions yielded similar estimates, they are regarded as being reasonably compatible. The Vehicle Maneuver definition could have been applied to both GES and FARS with similar results to those reported. However, the Accident Type definition was selected for GES since it is somewhat more specific and since it supports a more detailed analysis of SVRD crash subtypes.

Table 2-2 provides a summary of problem size statistics for all SVRD crashes for five different vehicle types: all vehicles, passenger vehicles (car, light truck, light van), combination-unit trucks, medium/heavy single-unit trucks and motorcycles. Appendix A, Section A.4, specifies the definitions of these vehicle type categories.

All statistics regarding crashes and non-fatal injuries provided in Table 2-2 were rounded to the 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 table were calculated before numbers were rounded.

Table 2-2 shows that overall in 1991:

- There were approximately 1.27 million police-reported SVRD crashes, which constituted 20.8 percent of all police-reported crashes. See **Figure 2-1.**

Figure 2-1
All Crashes: 6.110 Million

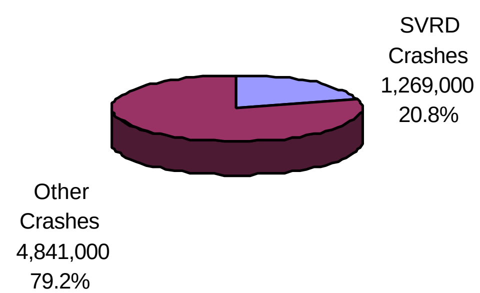


TABLE 2-2
PROBLEM SIZE ESTIMATE - SINGLE VEHICLE ROADWAY DEPARTURE CRASHES

GES/FARS-Based Statistics **(1991)**

		All Vehicles	Passenger Vehicles	C.U.T.	S.U.T.	Motorcycles
Annual # PR Crashes (GES)	Total:	1,269,000	1,200,000	25,000	16,000	19,000
	Injury:	441,000	417,000	5,000	3,000	14,000
	PDO:	828,000	782,000	21,000	13,000	5,000
Annual # Fatalities (FARS)		15,533	13,862	306	81	1,052
Ann. # Non-Fatal PR Injuries (GES)	Total:	574,000	544,000	5,000	4,000	15,000
	A:	121,000	112,000	1,000	1,000	6,000
	B:	234,000	221,000	2,000	1,000	8,000
	C	218,000	211,000	1,000	2,000	2,000
Fatal Crash Equivalents (FCEs)		28,213	25,640	474	195	1,649
Percentage of All PR Crashes		20.77%	20.11%	13.53%	12.37%	18.25%
Percentage of All **FCE**		30.72%	29.63%	10.54%	9.92%	29.26%
Percentage of All Fatalities		37.42%	36.31%	8.40%	6.97%	35.87%
Annual Involvements:						
Involvement Rate Per 100 Million VMT		58.4	59.8	26.2	29.9	205.2
Annual Involvements Per 1,000 Registered Vehicles		6.59	6.60	15.85	3.78	4.51
Expected # Involvements During Vehicle Life		**0.0865**	**0.0858**	0.2330	0.0556	0.0338
Estimated Annual # NPR Crashes	Total:	1,580,000	1,492,000	40,000	25,000	9,000
	Injury:	186,000	176,000	5,000	3,000	1,000
	PDO:	1,394,000	1,316,000	35,000	22,000	8,000
Estimated Total Annual Target Crashes (PR + NPR)	Total:	2849,000	2,692,000	65,000	41,000	28,000
	UDH:	356,000	339,000	11,000	3,000	2,000
	Non-UDH:	2,493,000	2,353,000	54,000	37,000	26,000
Crash-Caused Congestion (Delay)	Veh-Hours:	74.3 M	70.6 M	2.1 M	0.7M	0.6 M
Percentage of All Crash-Caused Delay		**1650%**	**15.69%**	0.47%	0.16%	0.14%

Legend:

A	Incapacitating Injuries	**M**	Million
B	Nonincapacitating Injuries	NPR	Non-Police Reported
C	Possible Injuries	PDO	Property Damage Only
CUT.	Combination-Unit Truck	PR	Police Reported
FARS	Fatal Accident Reporting System	S.U.T.	Single-Unit Truck
FCE	Fatal Crash Equivalent	UDH	Urban Divided Highway
GE5	General Estimates System	VMT	Vehicle Miles Traveled

There were 15,553 associated fatalities, which constituted 37.4 percent o total crash fatalities. **See Figure 2-2. ,**

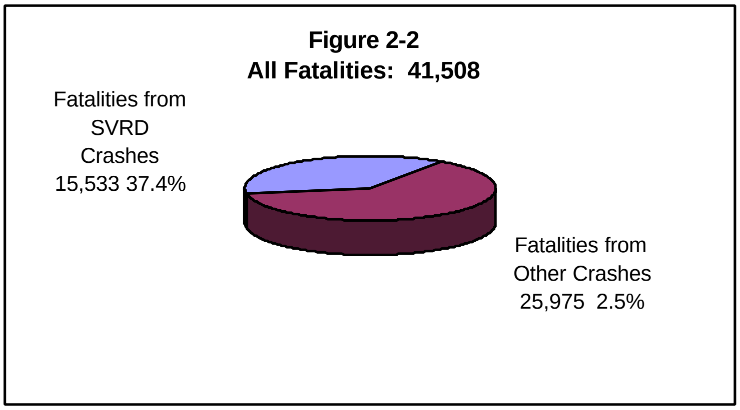


Figure 2-2
All Fatalities: 41,508

- SVRD crashes were associated with approximately 574,000 non-fatal police-reported injuries.

- SVRD crashes were associated with approximately 28,213 fatal crash equivalents (see Appendix A for definition and explanation).

- During its operational life, a vehicle could be expected to be involved in an average of 0.09 police-reported SVRD crashes.

- Based on the non-police-reported crash estimation algorithm (see Appendix A), there were approximately 1.58 million non-police-reported SVRD crashes in 1991. Therefore, there were about 2.85 million total SVRD crashes (police-reported plus non-police-reported) in 1991.

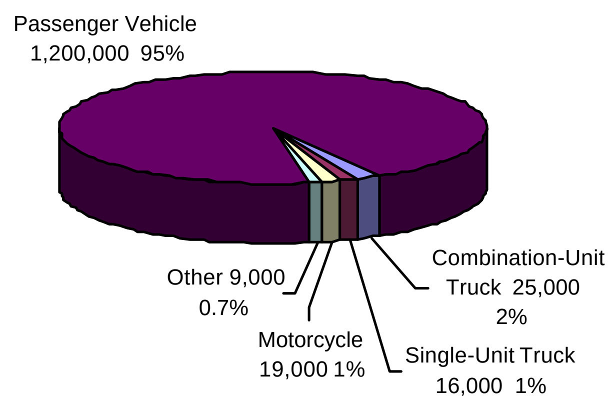
- SVRD crashes accounted for approximately 16.5 percent of all crash-caused delay. See Appendix A for an explanation of the delay estimation procedure.

2.2 Vehicle Type Comparisons

Table 2-2 also shows comparable statistics for four different vehicle types. Comparing passenger vehicle (car, light truck, light van) SVR D crashes to those of combination-unit trucks, single-unit trucks and motorcycles, one finds that:

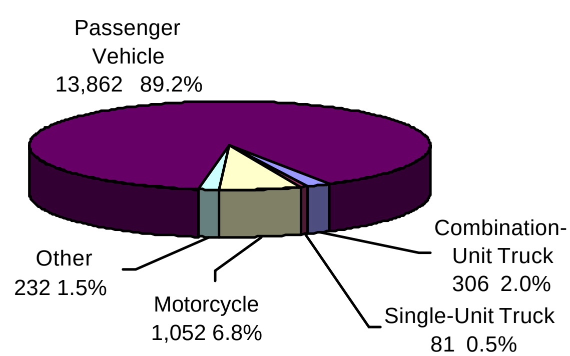
In terms of absolute number of involvements in SVRD crashes, there were far more passenger vehicle involvements (1.20 million) in 1991 than medium/heavy truck involvements (0.04 million, combination-unit and single-unit truck combined) or motorcycle involvements (0.02 million). **Figure 2-3** indicates the SVRD crash involvement distribution by vehicle type

Figure 2-3. SVRD Crashes by Vehicle Type
All SVRD Crashes: 1.269 Million

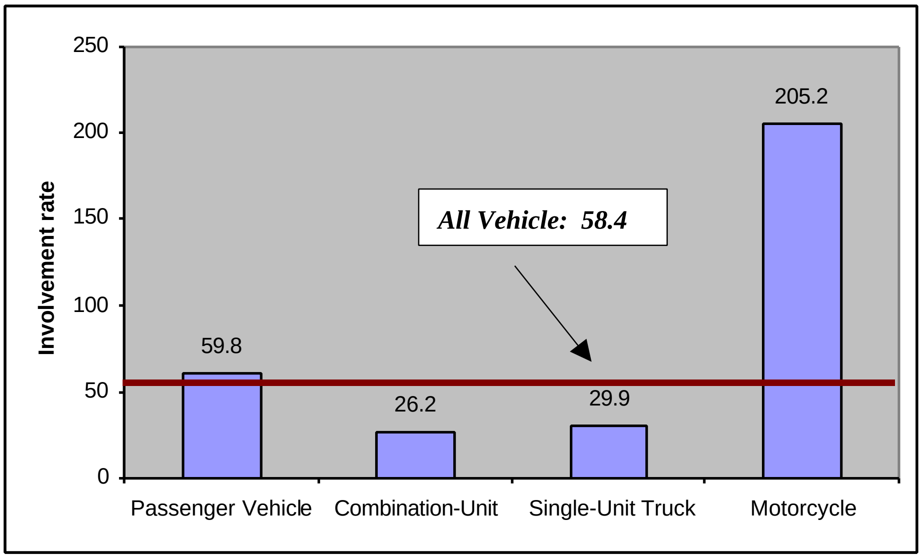


Of 15,533 associated fatalities, 89.2 percent were passenger vehicle occupants, 6.8 percent were motorcycle occupants and 2.5 percent were medium/heavy truck occupants. **Figure 2-4** compares SVRD fatalities by vehicle type.

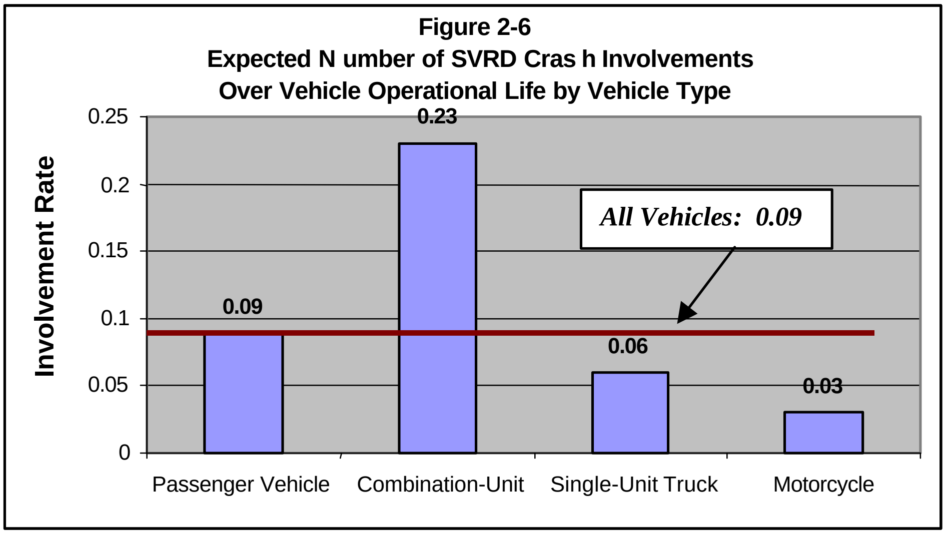
Figure 2-4. SVRD Crash Associated Fatalities
by Vehicle Type



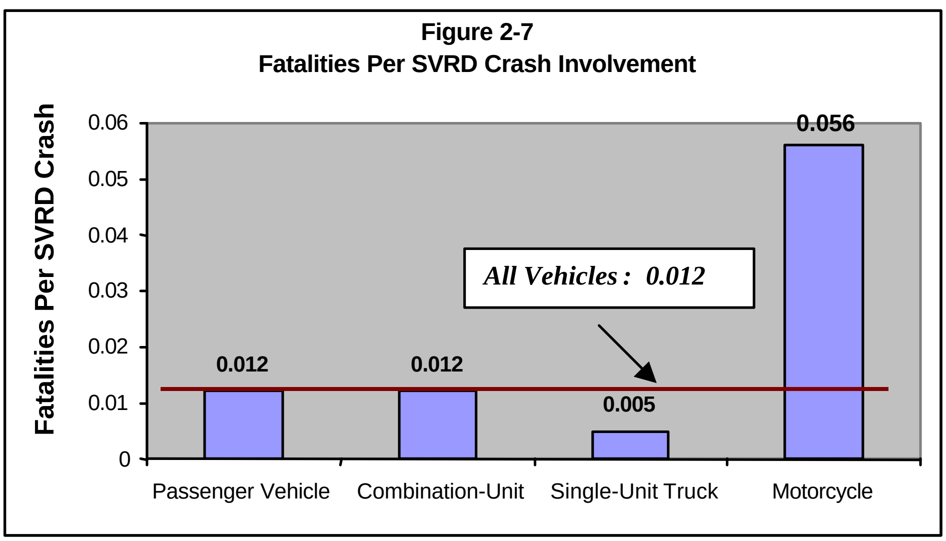
- **Figure 2-5** compares involvement rates per 100 Million VMT for passenger vehicles, combination-unit trucks, single-unit trucks and motorcycles. Based on VMT, motorcycles had a much higher target crash involvement rate (205.2 per 100 million VMT) than did passenger vehicles (59.8), single-unit trucks (29.9) o r combination-unit trucks (26.2).



Even though their involvement rates are low, individual combination-unit trucks are more likely to be involved in this crash during their operational lives than are other vehicle types. Based on the 1991 statistics, the average combination-unit truck could be expected to be involved in 0.23 SVRD crashes during its operational life, compared to a value of 0.09 for passenger vehicles, 0.06 for single-unit trucks and 0.03 for motorcycles. See **Figure 2-6**. This reversal for combination-unit trucks (i.e. lower **rate** but higher **likelihood** of involvement) is due to the much greater average mileage exposure of combination-unit trucks and the longer operational lives of heavy trucks compared to other vehicle types.



- One simple metric of relative crash severity is fatalities per police-reported SVRD crash involvement. **Figure 2-7** shows this ratio for five vehicle categories. Motorcycles have, by far, the highest ratio -- nearly five times that of other vehicle types.



In summary, the above statistics show that target passenger vehicle crashes constituted the vast majority of SVRD crashes. Motorcycles had the highest rates of involvement and highest incidence of fatalities per crash, but combination-unit trucks had the highest likelihood of involvement over vehicle life.

3. DESCRIPTIVE STATISTICS

Various bivariate distributions are provided for SVRD crash and fatal SVRD crashes. GES statistics, mostly derived from 1991 data, were used to describe the total population of SVRD crashes. Three new pre-crash variables in 1992 are also included to identify critical events and actions prior to a SVRD crash. Fatal crashes were described based on 1991 FARS statistics. For statistics of particular interest, corresponding percentage distribution charts are also presented. However, it is not within the scope of this report to interpret exhaustively every aspect of the statistics; instead, only key results are highlighted. The reader is encouraged to further analyze the data to identify observations or trends not discussed in this chapter. Also, a presentation of descriptive statistics for "all crashes" is beyond the scope of this report. The reader interested in comparing SVRD crashes to all crashes may compare this report to the GES and FARS annual reports.

For GES statistics, ***Imputed and Hotdeck imputed*** variables were used if available. In these variables, unknowns are distributed proportionately across known values. Statistics relating to the following variables from 1991 GES were obtained:

Imputed Time Blocks (i.e., 24:00-06:OO; 06:01-09:30; 09:31-15:30;
15:31-l8:30; 18:31-23:59)
Imputed Day of Week (AlCI, WKDY_I)
Percent Rural (A5A, RUR_URB)
Imputed Relation to Junction (AO9I, RELJCT_I)
Trafficway Flow (All , TRAF_WAY)
Imputed Roadway Alignment (A13I, ALIGN-I)
Imputed Roadway Profile (A14I, PROFIL-I)
Imputed Roadway Surface Condition (A15I, SURCON_I)
Hotdeck Imputed Speed Limit (A18i, SPDLIM-H)
Imputed Light Condition (A19I, LGTCON_I)
Imputed Atmospheric Condition (A20I, WEATHR_I)
Imputed Alcohol Involved in Crash (A92I, ALCHL_I)
Hotdeck Imputed Most Harmful Event (V20I, V_EVNT_H)
Imputed Vehicle Maneuver (V211, MANEUV_I)
Vehicle Accident Type (V23, ACC_TYPE)
Hotdeck Imputed Initial Point of Impact (V24H, IMPACT-H)
Imputed Violations Charged (D2I, VLTN_I)
Driver's Vision Obscured By . . . (D04, VIS_OBSC)
Driver Distracted By . . . (D07, DR_DSTRD)
Hotdeck Imputed Driver's Age (P7H, AGE-H) of Driver
Hotdeck Imputed Driver's Sex (P8H, SEX-H) of Driver
Person's Physical Impairment (P18, IMPAIRMT)

In addition, the following pre-crash variables from 1992 GES were obtained:

Critical Event (V26,, P-CRASH2)
Corrective Action Attempted (A27, P-CRASH3)
Vehicle Control After Corrective Action (A28, P-CRASH4)

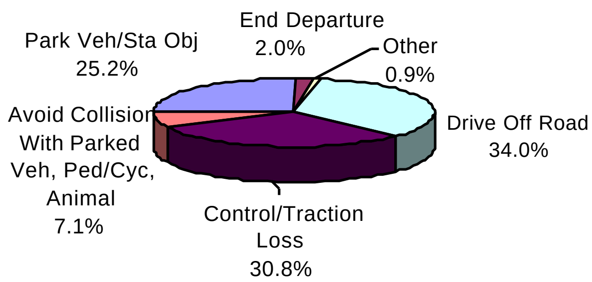
Selected descriptive statistics on fatal SVRD crashes are provided for comparison. The following variables from FARS were obtained:

Time Block (24:00-06:00, 06:01-09:30, 09:31-15:30, 15:31-l8:30, 18:31-23:59)
Day of Week
Roadway Function Class (A36, ROAD-FNC)
Roadway Alignment (A64, ALIGNMNT)
Roadway Surface Condition (A70, SUR-COND)
Driver's age - 10 year blocks; 15-24, 25-34, etc (P16, AGE)
Driver Sex (P18, SEX)
Blood Alcohol Concentration (BAC)
Related Factors 1 - Driver Level (D46, DR-CFl)
Related Factors 2 - Driver Level (D48, DR-CF2)
Related Factors 3 - Driver Level (D50, DR-CF3)

The following major findings are noted. For each specific variable (whether GES non-imputed or FARS), the percentage cited here is the proportion of known values. Generally, statistics are provided for all vehicle types combined, passenger vehicles, and combination-unit trucks. Due to their relatively small GES sample sizes, descriptive statistics are generally not provided for single-unit trucks and motorcycle SVRD crashes.

Accident Type

Figure 3-l shows the proportions of various SVRD subtypes regardless of impact direction (left, right or forward). Three frequent pre-crash situations were: drive off road (34.0 percent), control/traction loss (30.8 percent) and forward impact to a parked vehicle/stationary object (25.2 percent).

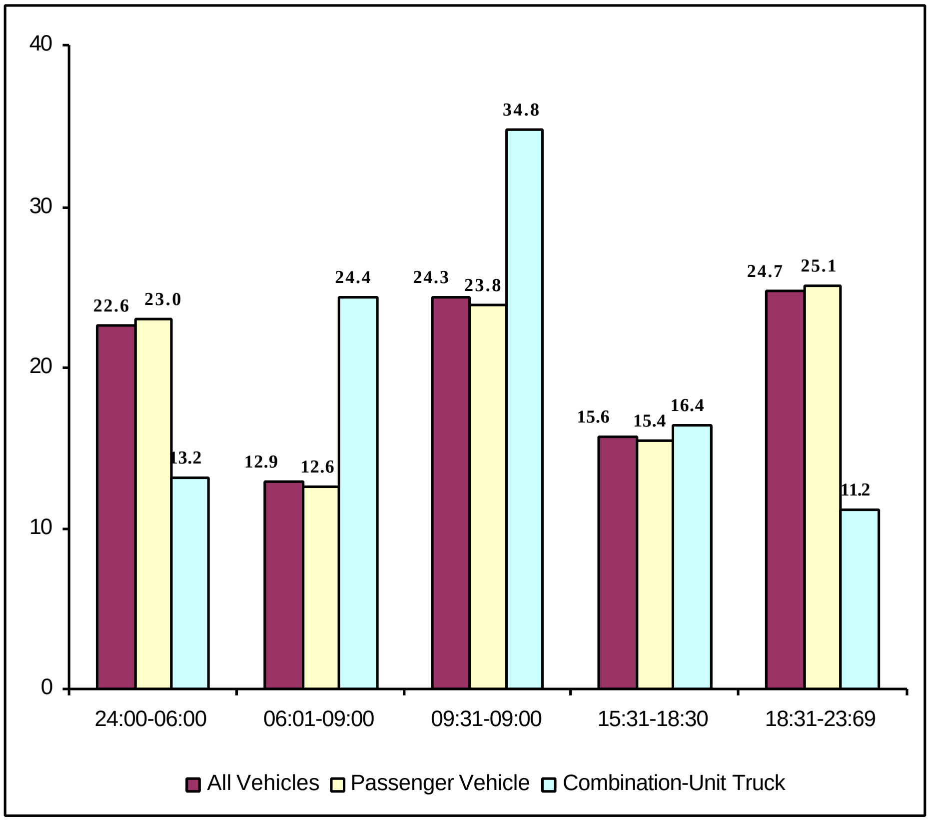


Note: All SVRD Crashes: 1.27 Million

- **Time of Day .**

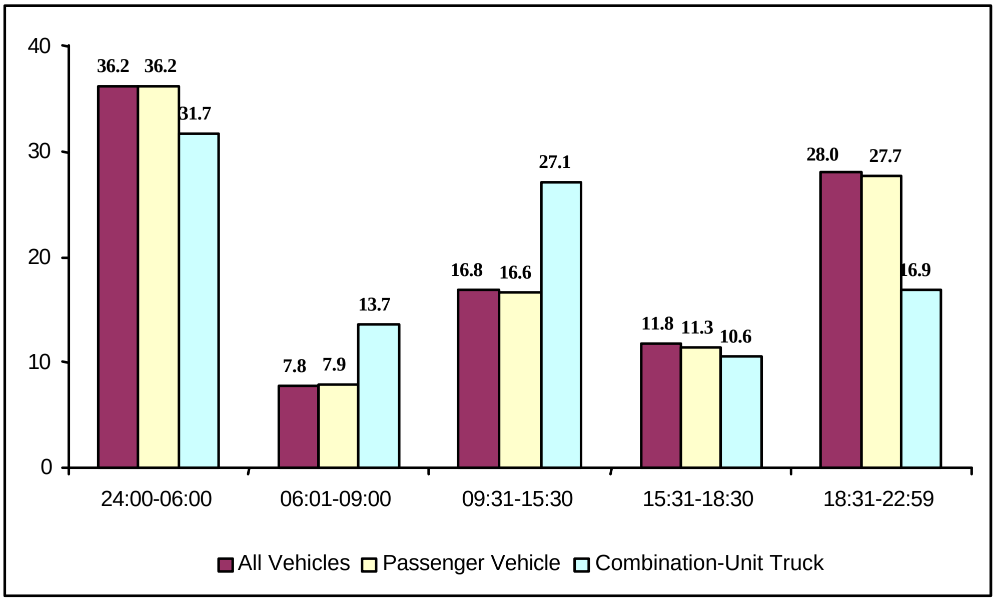
All SVRD Crashes. Overall, about 47.1 percent of SVRD crashes occurred during nighttime hours (18:31-06:OO) while 28.4 percent occurred during rush hours (morning: 6:01-9:30 plus afternoon: 15:31-18:30). About 40.7 percent of target combination-unit truck crashes occurred during rush hours and 24.4 percent occurred during nighttime hours; **Figure 3-2A** graphically presents the comparison for the three predefined vehicle types.

Figure 3-2A. Time of Day by Vehicle Type SVRD Crashes



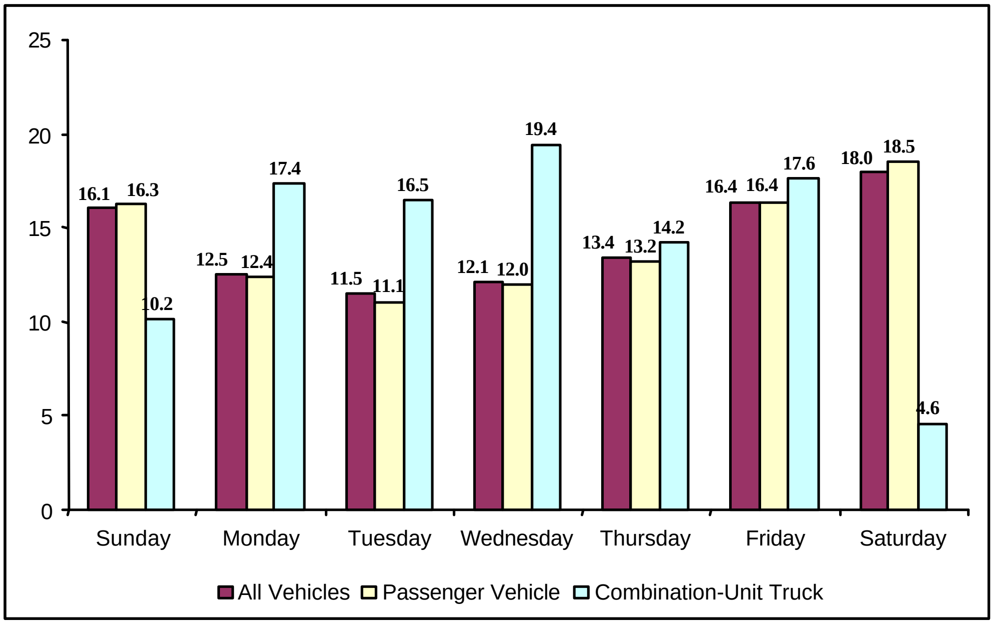
<u>Fatal SVRD Crashes</u>. A high percentage of fatal SVRD crashes -- 64.2 percent -- occurred during nighttime hours (18:31 to 6:OO). In particular, there were many fatal SVRD crashes between midnight and 6:00 am (36.2 percent). **Figure 3-2B** compares the three vehicle types.

Figure 3-2B. Time of Day by Vehicle Type
Fatal SVRD Crashes



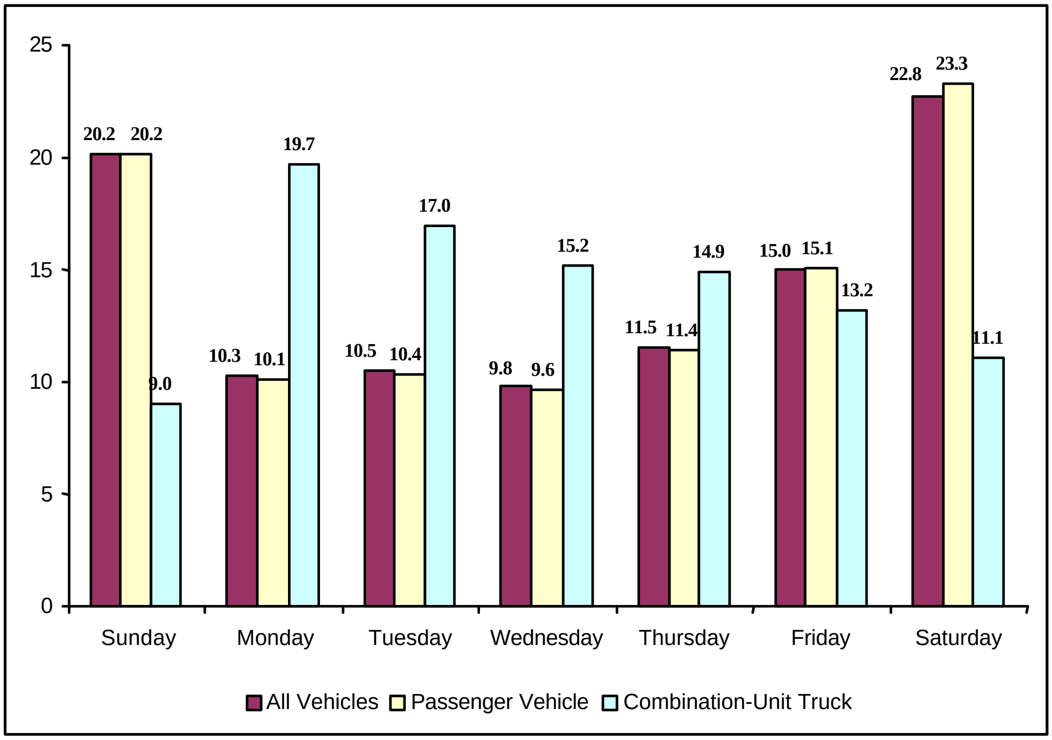
- **Day of Week**

All SVRD Crashes Regarding day-of-week, target passenger vehicle crashes more likely took place on Friday and weekends. Target combination-unit truck crashes occurred more frequently on weekdays. **See Figure 3-3A.**



Fatal SVRD Crashes. Nearly 43.0 percent of fatal SVRD crashes occurred on weekends. However, target combination-unit truck crashes showed a different pattern **(See Figure 3-3B).** The target combination-unit truck crashes occurred more frequently on weekdays than weekends.

Figure 3-3B. Day of Week by Vehicle Type
Fatal SVRD Crashes

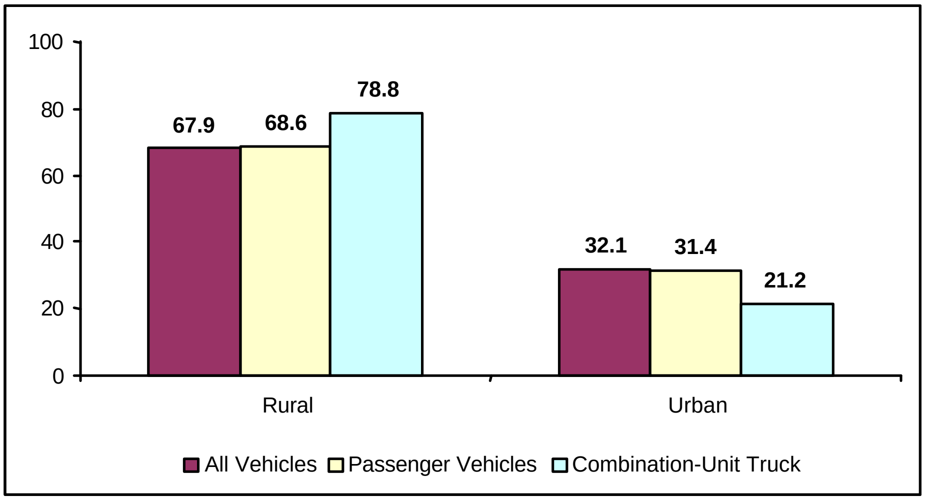


- **Rural/Urban**

All SVRD Crashes. At this writing, data to support a rural versus urban breakout for all SVRD crashes are not available.

Fatal SVRD Crashes. **Figure** 3-4 shows that over two-thirds of fatal SVRD crashes occurred in rural areas.

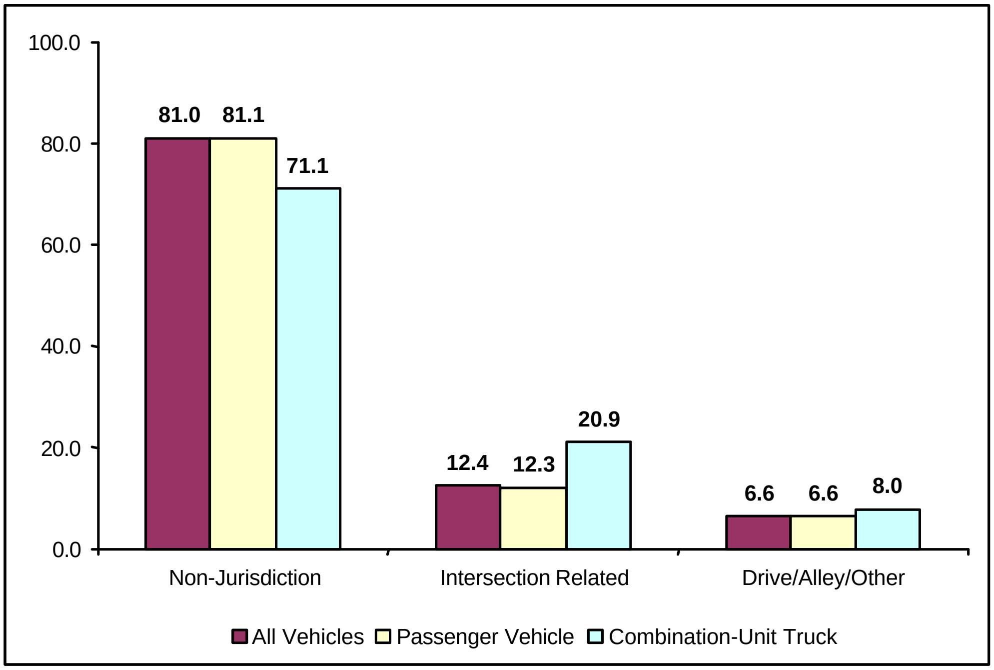
Figure 3-4. Rural/Urban by Vehicle Type
Fatal SVRD Crashes



- **Relation to Junction**

Most SVRD crashes were non-junction related. Overall, about 12.4 percent of SVRD crashes took place in intersections or were intersection-related. Target combination-unit truck crashes had a somewhat higher percentage of intersection or intersection-related **crashes. See Figure 3-5.**

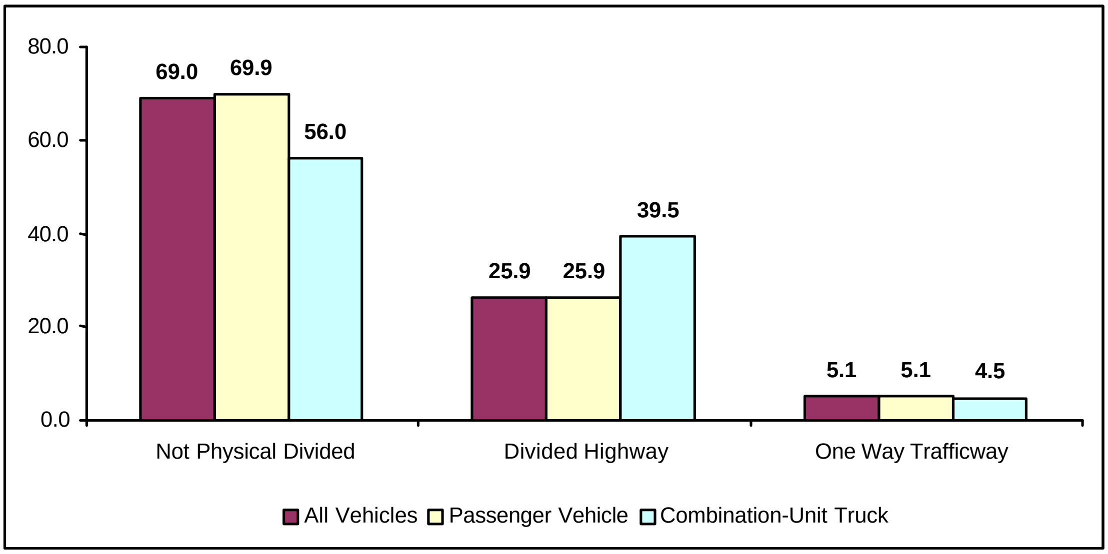
Figure 3-5. Relation of Junction by Vehicle Type
SVRD Crashes



- **Trafficway Flow**

Unknown rates for this variable were high - approximately 35.5 percent. However, for the known values, about 25.9 percent of SVRD crashes occurred on divided roadways. Not surprisingly, **Figure 3-6** shows that target combination-unit truck crashes occurred relatively frequently more on divided highways than did target passenger vehicle crashes.

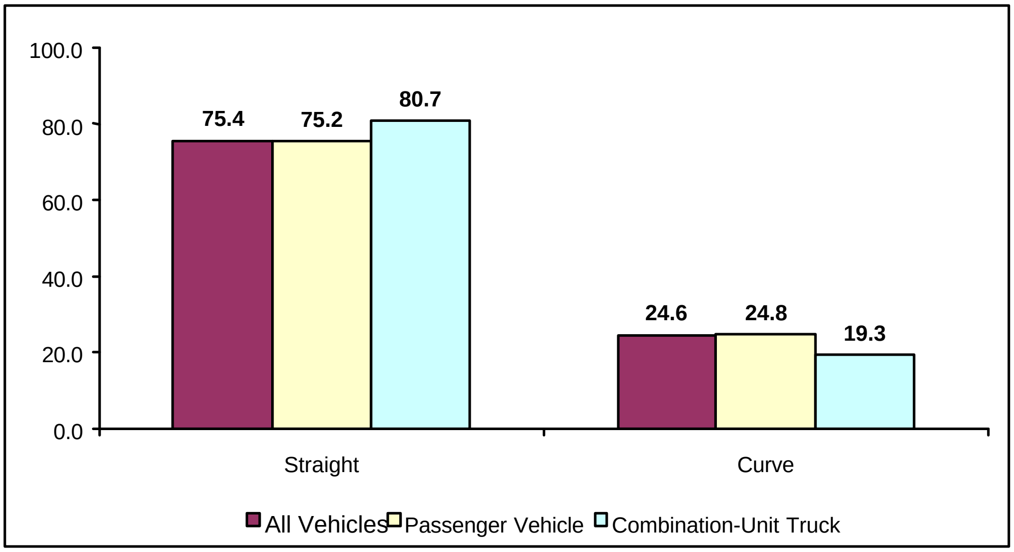
Figure 3-6. Trafficway Flow by Vehicle Type
SVRD Crashes



- **Roadway Alignment**

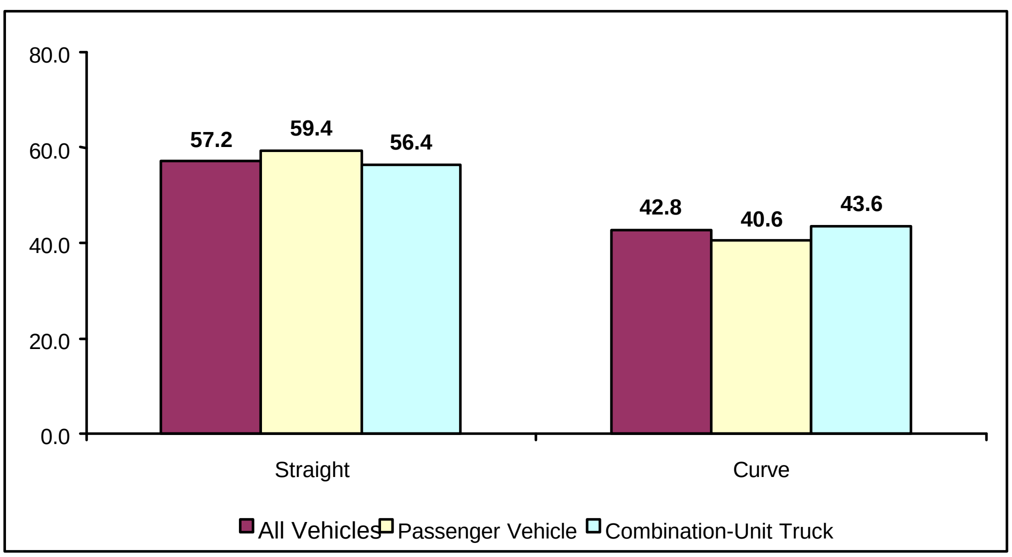
All SVRD Crashes. About 75.4 percent of SVRD crashes occurred on straight roadway sections, while 24.6 percent occurred on curves. There was little difference between passenger vehicles and combination-unit trucks. See **Figure 3-7A.**

Figure 3-7A. Roadway Alignment by Vehicle SVRD Crashes



Fatal SVRD Crashes. Compared to all SVRD crashes, a larger percentage of fatal SVRD crashes (42.8 percent) occurred on curved roadways sections. See **Figure 3-7B**.

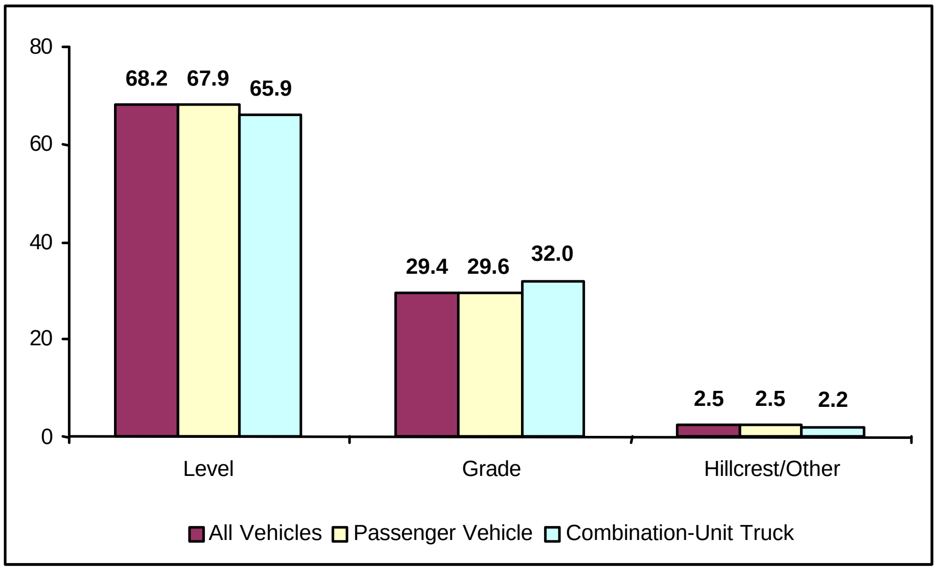
Figure 3-7B. Roadway Alignment by Vehicle Type Fatal SVRD Crashes



- **Roadway Profile**

Most SVRD crashes occurred on level roadway sections. Of cases with known roadway profile, about two-thirds occurred on level roadways, with little difference between passenger vehicles and combination-unit trucks. **See Figure 3-8.**

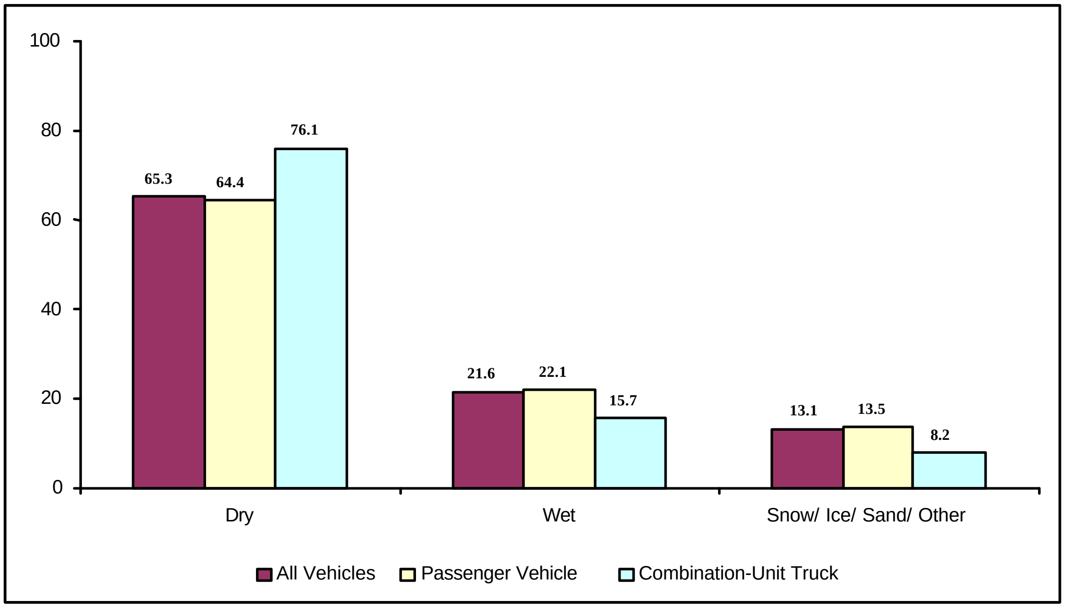
Figure 3-8. Roadway Profile by Vehicle Type
SVRD Crashes



- **Roadway Surface Condition**

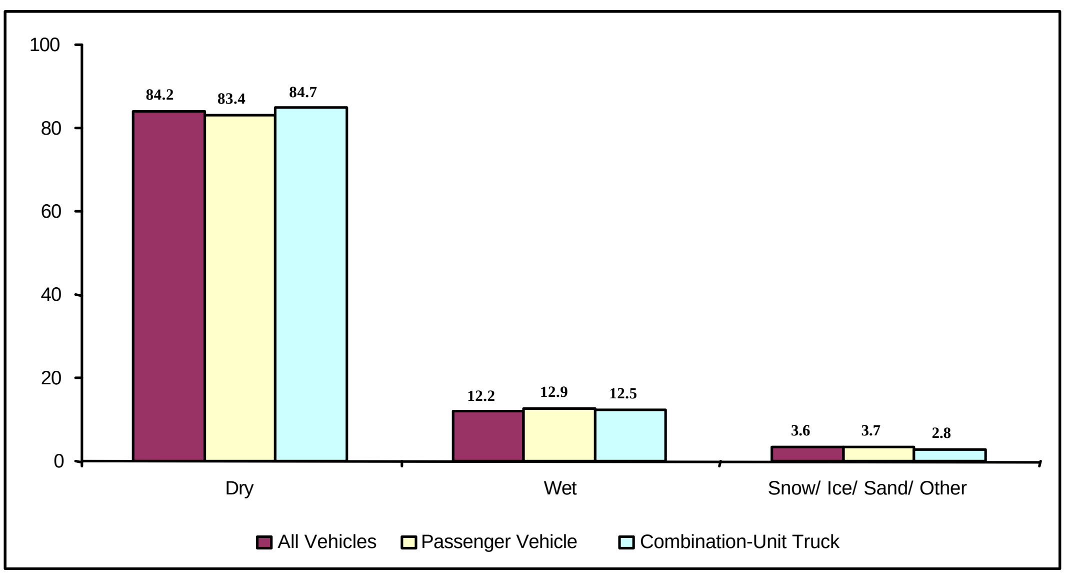
All SVRD Crashes. About 65.3 percent of SVRD crashes occurred on dry pavement, 21.6 occurred on wet roadway and 13.1 percent occurred on snowy/icy/ "other" roadways. There was little difference between passenger vehicles and combination-unit trucks. **See Figure 3-9A.**

Figure 3-9A. Roadway Surface Condition by Vehicle Type
SVRD Crashes



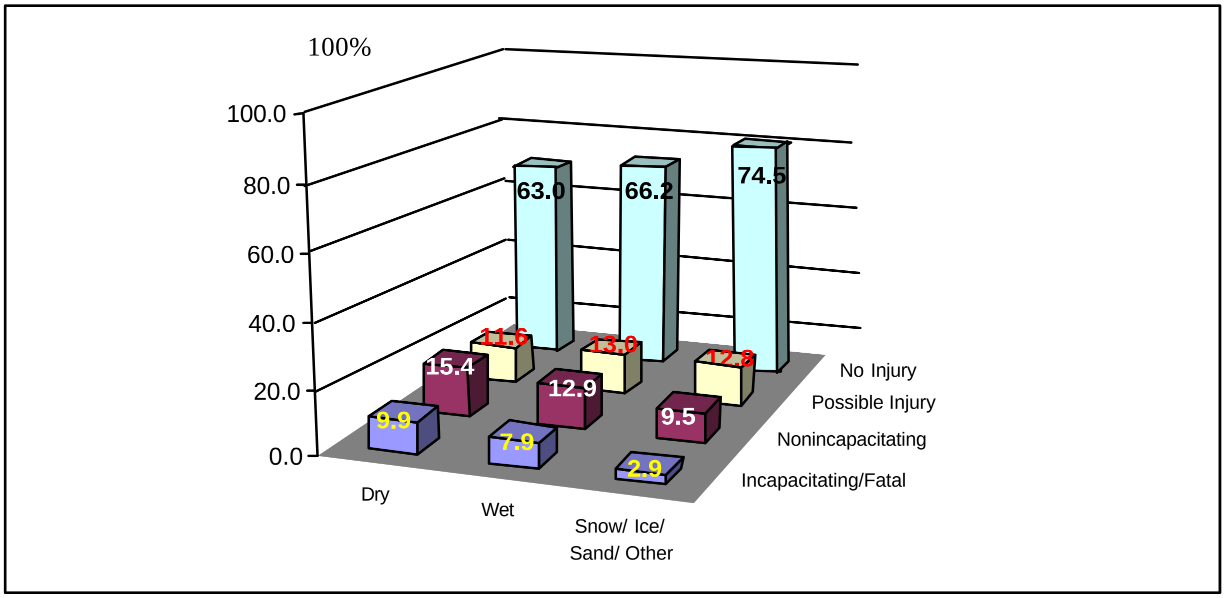
Fatal SVRD Crashes. About 84.2 percent of fatal SVRD crashes occurred on dry pavement. About 12.2 percent occurred on wet pavement and 3.6 percent occurred on snow/ice/sand/"other" roadway surfaces. There was little difference between passenger vehicles and combination-unit trucks. See Figure 3-9B. The relatively small involvement of potentially-slippery roadway surfaces in fatal SVRD crashes compared to all SVRD crashes is notable.

Figure 3-9B. Roadway Surface Condition by Vehicle Type
Fatal SVRD Crashes



GES Roadway Surface by Severity. The tendency for SVRD crashes occurring on dry roadways to be more severe than those occurring on slippery roadways is also show n **in Figure 3-9C** below.

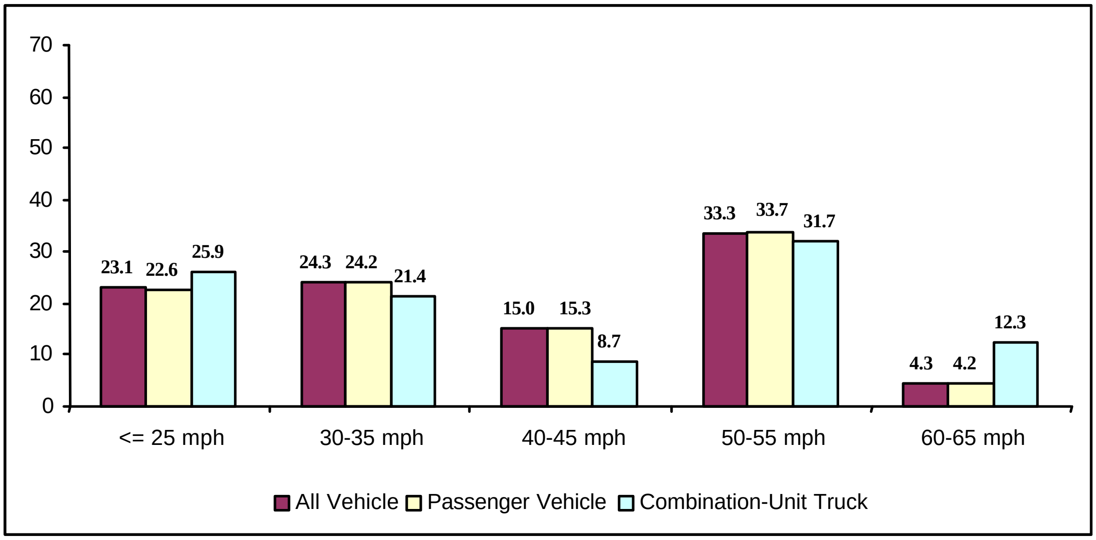
Figure 3-9C Severity-by Roadway Surface Condition SVRD Crashes



- **Speed Limit**

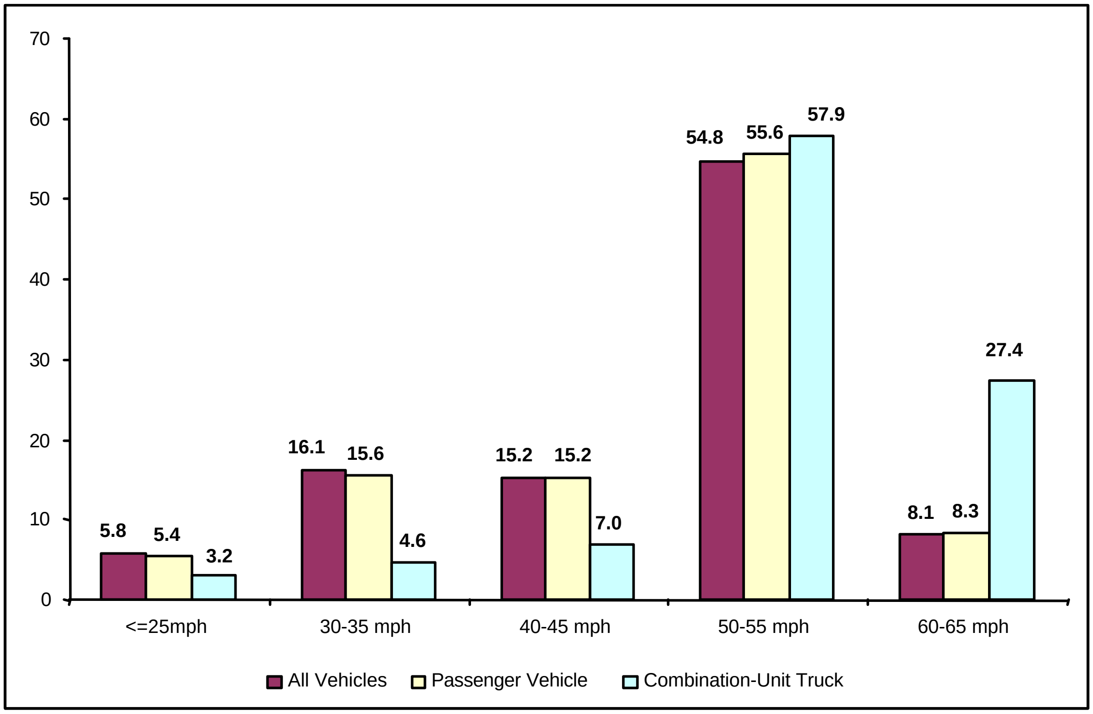
<u>All SVRD Crashes</u>. SVRD crashes most frequently occurred on 50-55 mph roadways. Figur e **3-10A** shows that 12.3 percent of target combination-unit truck crashes occurred on 60-65 mph roadways, which was about three times the percentage for passenger vehicles.

Figure 3-10A. Speed Limit by Vehicle Type SVRD Crashes



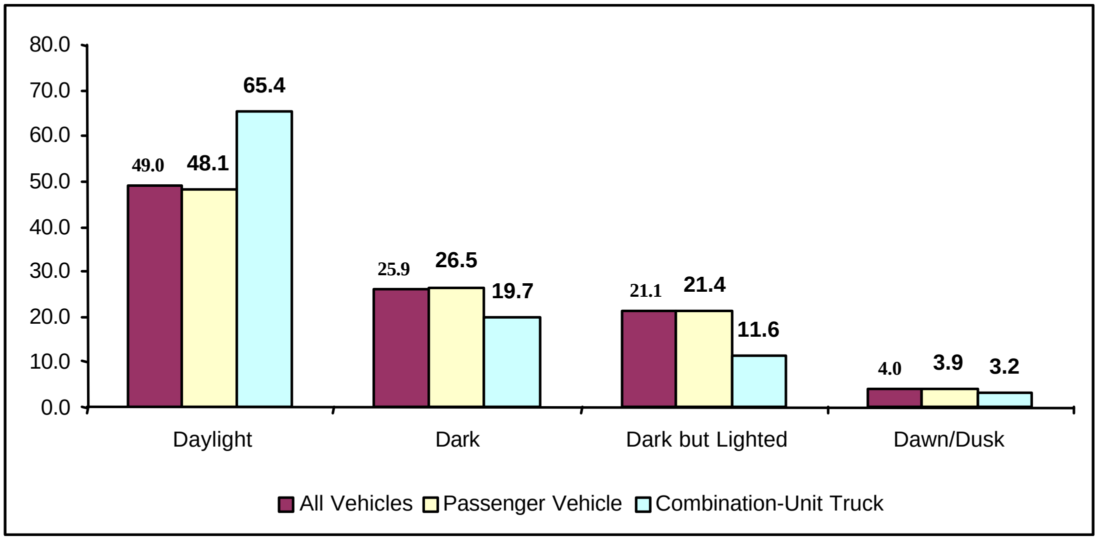
Fatal SVRD Crashes. More than half of the fatal SVRD crashes occurred on 50-55 mph roadways. **Figure 3-10B** shows that 27.4 percent of fatal target combination-unit truck crashes occurred on 60-65 mph roadways, which was relatively high, when compared to passenger vehicles.

Figure 3-10B. Speed Limit by Vehicle Type
Fatal SVRD Crashes



- **Light Condition**
  Approximately 70.1 percent of target crashes occurred during daylight or on dark but lighted roadways. **See Figure 3-11** for a percentage breakdown for different vehicle types. Note that relatively more combination-unit truck SVRD crashes occurred under daylight conditions .

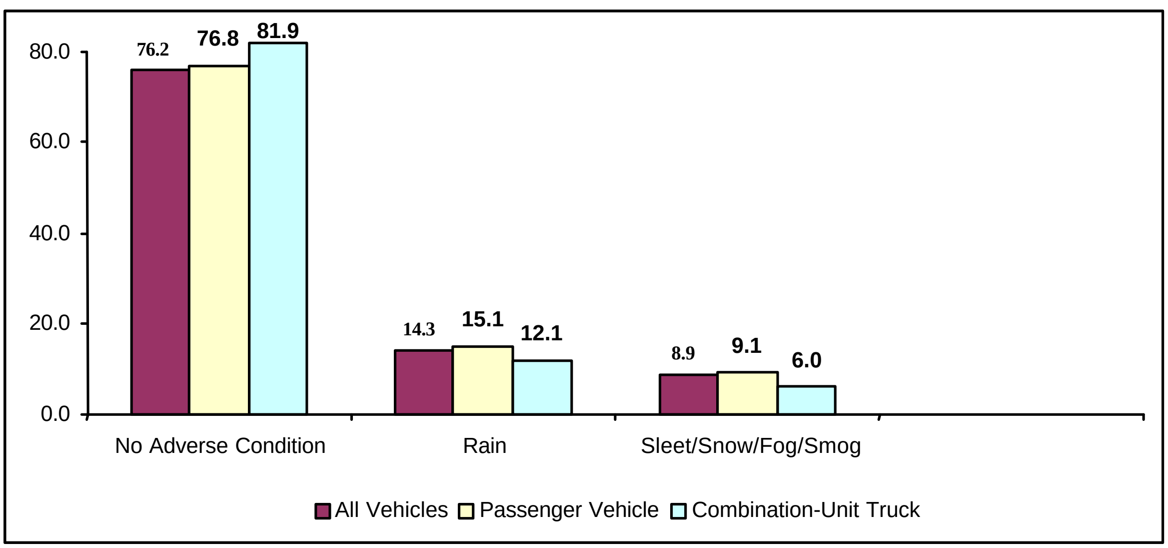
Figure 3-11. Light Condition by Vehicle Type
SVRD Crashes



- **Weather**

Figure 3-12 shows that 76.2 percent of SVRD crashes occurred under no adverse weather conditions, 14.9 percent occurred during rain, and 8.9 percent during other (e.g. sleet, snow, etc.) weather conditions. There is, little difference between passenger vehicles and combination-unit trucks.

Figure 3-12. Weather Conditions by Vehicle Type
SVRD Crashes



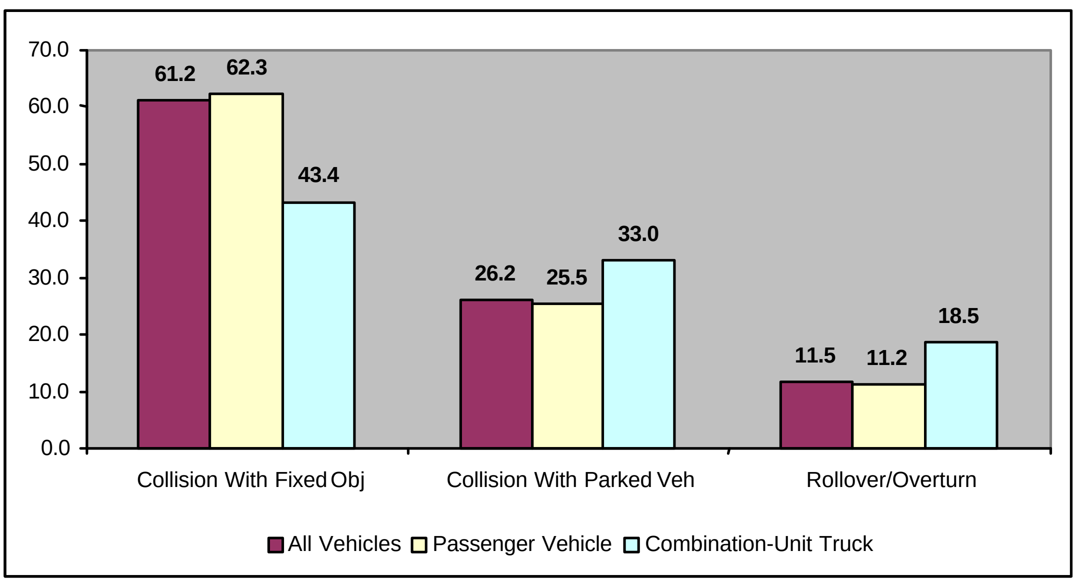
- **Point of Impact**
  The most frequent points of impact for SVRD crashes were front (51.4 percent), right side (20. I percent) and left side (12.3 percent) However, for combination-unit trucks right side impacts were slightly more frequent (30.0 percent) than frontal impacts (27.7 percent)

- **First Harmful Event**

  The most common first harmful events were:
  - Collision with fixed objects (61.2 percent)
  - Collision with parked vehicles (26.2 percent)
  - Rollover/Overturn (11.6 percent).

  Figure 3-13 presents the percentage distributions of the most common first harmful events for all three vehicle types. . Note that collisions with parked vehicles and rollover/overturn represented a relatively greater portion of combination-unit truck SVRD crashes.

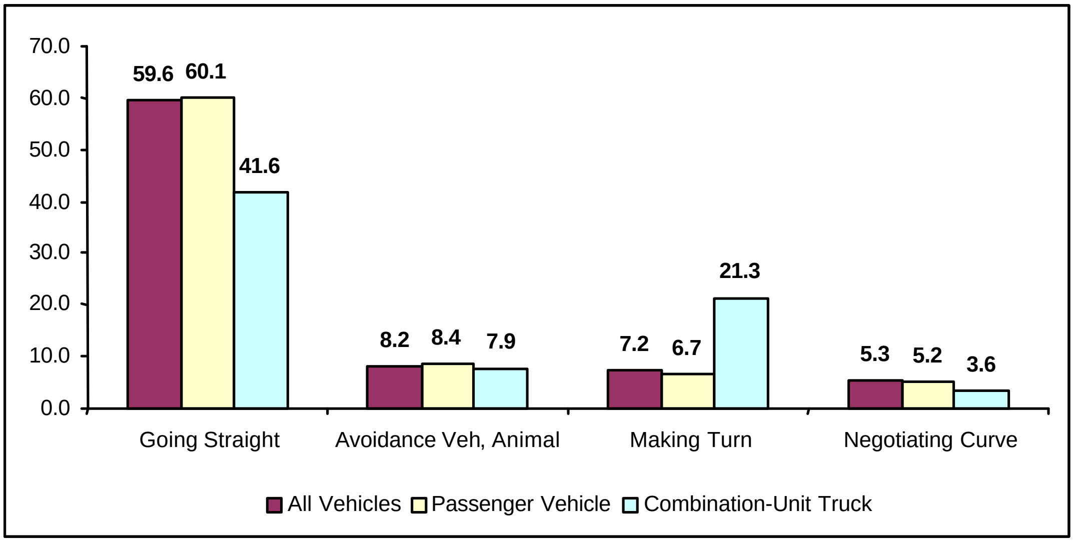
Figure 3-13. Most Common First Harmful Events by Vehicle Type - SVRD Crashes



- **Pre-crash Maneuver**

The most common vehicle pre-crash maneuver, representing about 59.6 percent of vehicles, was "going straight". Approximately 8.2 percent of vehicles were making an avoidance maneuver (e.g., other vehicles,-animals in roadway). Making turns (7.2 percent) was also a common pre-crash maneuver, especially for combination-unit trucks. Finally, 5.3 percent were negotiating a curve. However, refer to the. roadway alignment statistics presented earlier relating to crashes on curves. **Figure 3-14** depicts the distribution.

Figure 3-14. Most Common Pre-crash Maneuvers by Vehicle Type - SVRD Crashes



- **Jackknife**

For combination-unit SVRD crashes, jackknife was also a common first harmful event (6.6 percent).

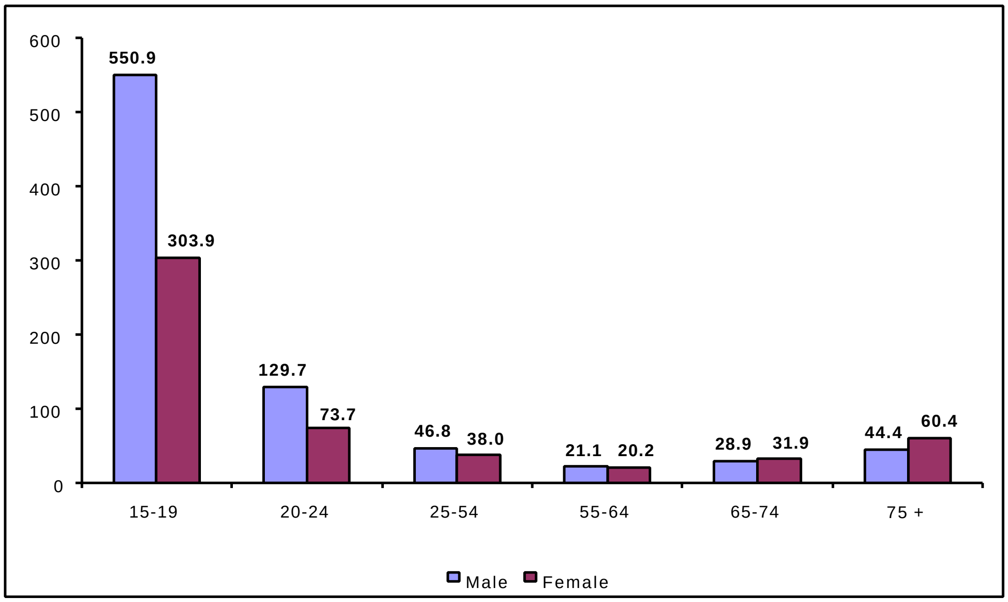
- **Rollover**

Overall, about 14.1 percent of the SVRD crashes involved rollover, either as the most harmful event (11.6 percent) or other event in the crashes. Target combination-unit truck crashes had a higher rollover involvements (22.3 percent, 18.5 as most harmful event) than did target passenger vehicle crashes (14.2 percent, 11.2 as most harmful event).

- **Crash Involvement Rate Based on VTM by Driver Age and Sex** to unavailability of 1991 VMT data by driver age and sex, crash and fatal crash involvement rates were calculated using 1990 data, including VTM data from the Nationwide Personal Transportation Study (Pisarsk, 1992). Driver information also was retrieved from 1990 GES.

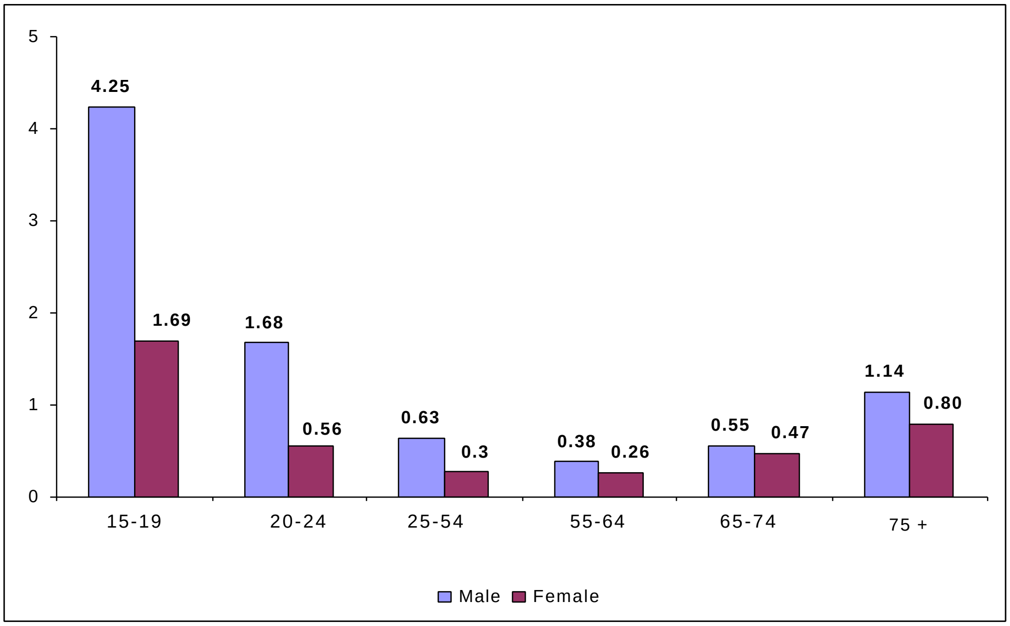
All **SVRD** Crashes. **Figure 3-15A** shows that teenaged drivers had the highest rate of SVRD crash involvement. Involvement rates decreased with advancing age though the 55-64 age group, and then increased somewhat for older drivers. Male crash involvement rates were higher in each age group between age 15 and 64. For driver ages between 15 and 24, the crash involvement rate of male drivers was about two times that of female drivers. Overall, males had a considerably higher involvement rate (68.5 per 100 million vehicle miles traveled) than did females (52.1 per 100 million VMT).

Figure 3-15A. SVRD Crash Involvement Rate by Driver Age and Sex (1990 Data)



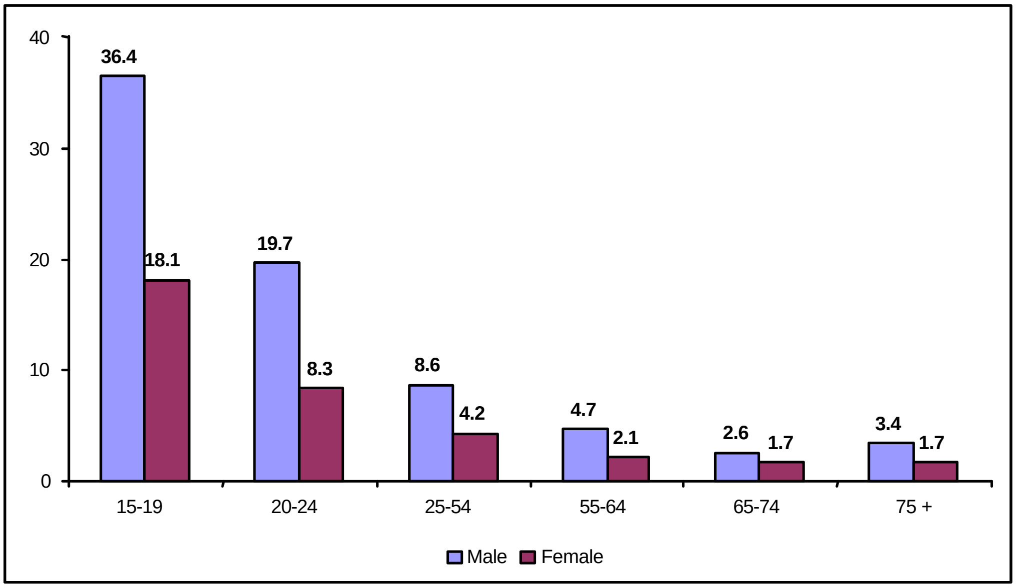
Fatal **SVRD** Crashes. **Figure 3-15B** indicates that male fatal crash involvement rates were higher in each age group. Both male and female drivers display the familiar "U-shaped" pattern in change of the fatal target crash involvement rate by age, with the highest rates for younger drivers and the lowest for middle-aged drivers.

Figure 3-l 5B. Fatal SVRD Crash Involvement Rate by Driver Age and Sex (1990 Data)



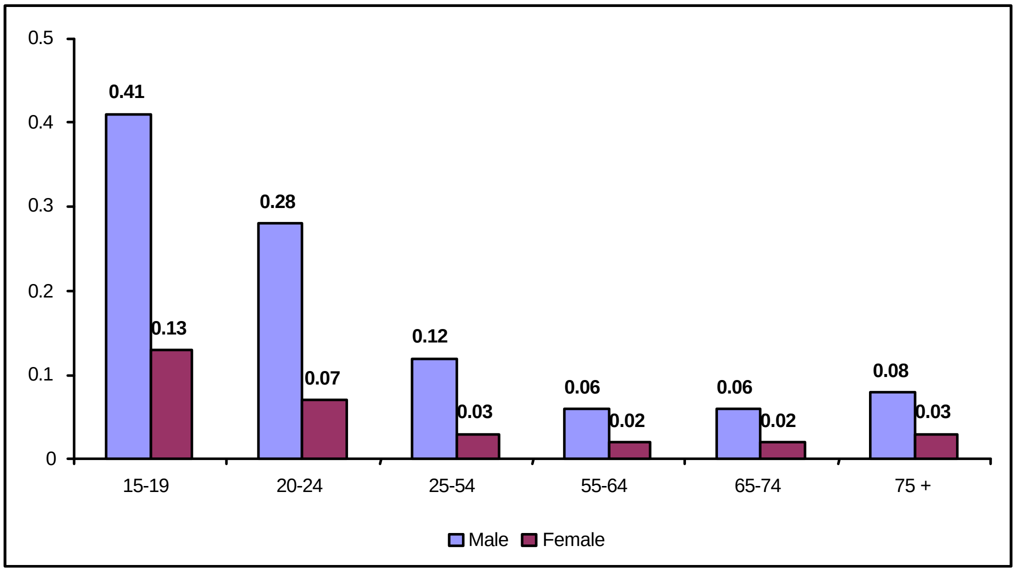
- **Crash Involvement Likelihood Based on Licensed Drivers by Driver Age and Sex** All SVRD Crashes. The involvement pattern based on number of licensed drivers is similar to that based on the VMT. **Figure 3-16A** shows that the risk of involvement for teenagers was the highest among all age groups. There were 36 SVRD crash involvements per 1,000 teenaged drivers, compared to less than 5 SVRD crash involvements per 1,000 licensed drivers aged 55 and older. Overall, the likelihood of involvement for male drivers was twice that of female drivers (10.0 SVRD crash involvements/per 1,000 male drivers to 4.7 SVRD crash involvements per 1,000 female drivers)

Figure 3-16A. SVRD Crash Involvement Likelihood by Driver Age and Sex (1990 Data)



- **Fatal SVRD Crashes**. **Figure 3-16B** indicates that male fatal crash involvement likelihood were higher in each age group. Similar to the fatal crash involvement pattern based on VMT (Figure 3-15B), the risk of involvement in fatal SVRD crashes was highest for teenaged drivers and lowest for middle-aged drivers.

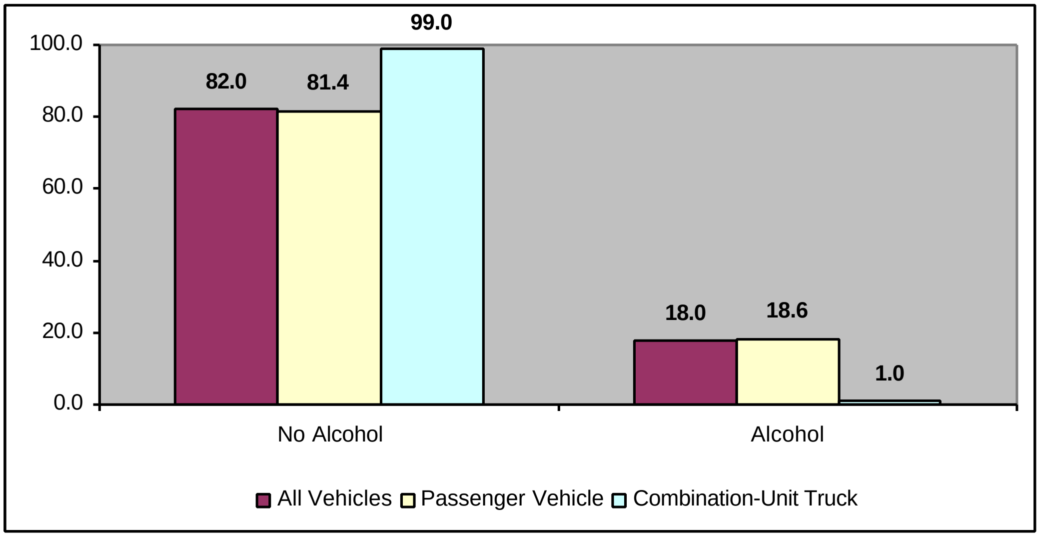
Figure 3-16B. Fatal SVRD Crash Involvement Likelihood by Driver Age and Sex (1990 Data)



- **Alcohol Involvement**

All SVRD Crashes. An estimated 18.6 percent of passenger vehicle target crashes involved alcohol (as recorded on the police accident report), compared to only 1.0 percent of combination-unit truck target crashes. See **Figure 3-17A.**

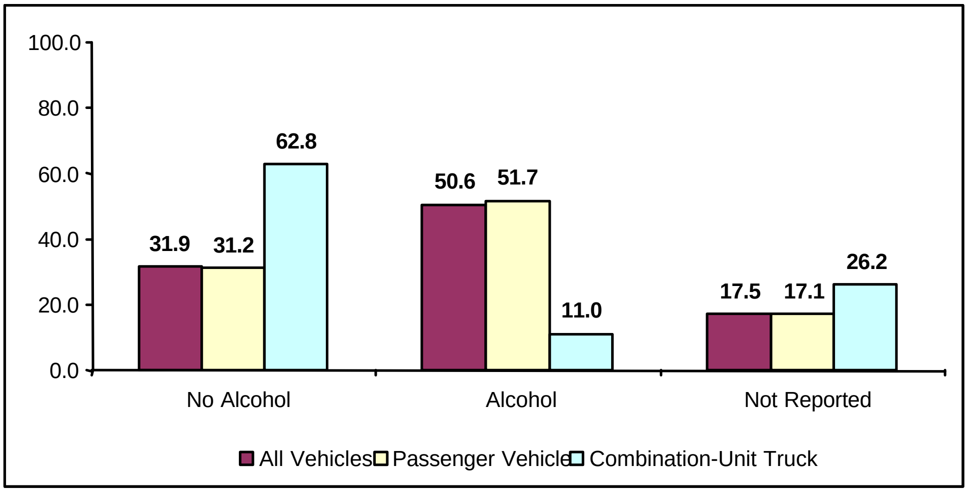
Figure 3-17A. Alcohol Involvement by Vehicle Type SVRD Crashes



Fatal SVRD Crashes. The 1991 FARS Blood Alcohol Concentration (BAC) Distribution File (accident level) was used to estimate alcohol involvement in SVRD fatal crashes. See Figure 3-17B, which shows drivers BAC levels for all vehicles, passenger vehicles and combination-unit trucks. Overall, 60.1 percent of SVRD fatal crashes involved alcohol (BAC 0.01 and above). Of the 60.1 percent alcohol involved SVRD crashes, 50.2 percent were high alcohol involvement (BAC 0.1 and above) crashes and 9.9 were low alcohol (BAC .Ol-.09). About 60.8 percent of fatal target passenger vehicle crashes involved alcohol, versus 16.7 percent alcohol involvement for fatal combination-unit truck SVRD crashes.

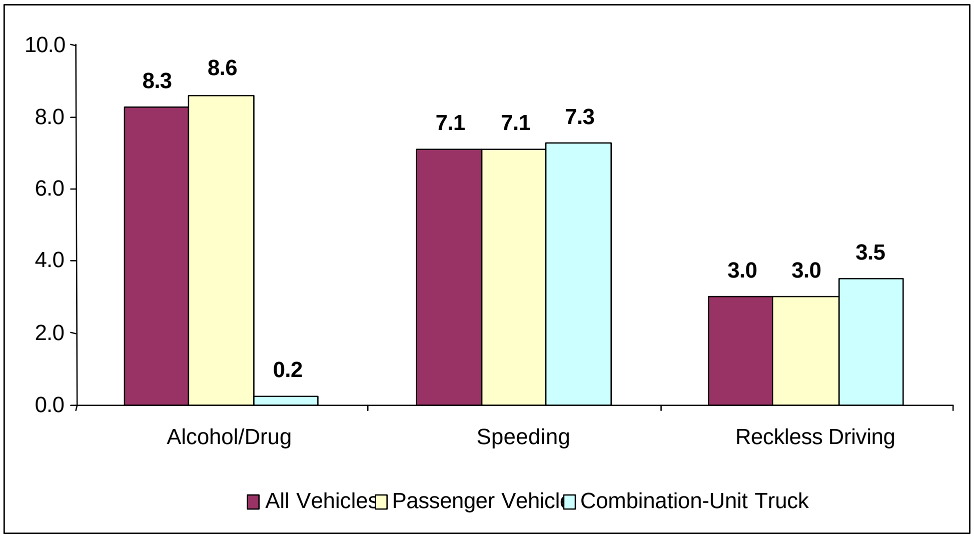
Not shown in Figure 3-17B is alcohol involvement in fatal motorcycle SVRD crashes. These percentages were: 3 1.4 percent no alcohol involved, 12.4 percent low alcohol involved and 56.2 percent high alcohol involved. Thus, the role of alcohol involvement in fatal motorcycle SVRD crashes is greater than that for passenger vehicles or combination-unit trucks.

Figure 3-1 7B. Alcohol Involvement by Vehicle Type
Fatal SVRD Crashes



- **Violation Charged**
  The most common violations charged were alcohol/drugs, speeding, and reckless driving, although alcohol/drug violations were rare for combination-unit truck drivers. **Figure 3-18** shows the trends for all three vehicle types.

Figure 3-18. Most Common Violation Charged
by Vehicle Type - SVRD Crashes



- **Physical Impairment and Other Driver Factors**

All SVRD Crashes. Overall, the physical conditions of 17 percent of SVRD drivers were coded as unknown. For all those with known physical conditions, 6.6 percent of SVRD drivers were cited as having some kind of physical impairment; 4.4 percent were drowsy or sleepy. **Table 3-l** below shows the percentage distribution of SVRD driver physical condition for three vehicle types. As indicated, combination-unit truck drivers had a higher drowsy/sleepy percentage than did passenger vehicle drivers.

Table 3-l. Physical Impairment by Vehicle Type
SVRD Crashes

Physical Impairment	All Vehicles	Passenger Vehicles	Combination-Unit Trucks
None	**93.4%**	**93.3%**	**93.1%**
Drowsy, Sleepy	4.4%	4.5%	6.2%
Ill, Blackout	**0.9%**	**1.0%**	0.2%
Other	**1.3%**	1.2%	0.5%
Total	100.0%	100.0%	100.0%

Note: The percentage is the proportion of known values.

Fatal SVRD Crashes. There is no comparable variable in FARS to describe driver physical conditions. In order to accomplish a similar comparison to the GES data on all SVRD crashes, three levels of driver-related factors were used. **Table 3-2 is** a list of the most frequently-cited driver factors. It is notable that 15.2 percent of fatal SVRD crash combination-unit truck drivers were drowsy or asleep, versus 7.3 percent of passenger vehicle drivers.

Most frequently-cited were the driver factors of driving too fast (50.5 percent of drivers)) inattentive (10.4 percent), and erratic/reckless driving (9.1 percent).

Since three different driver factors could be cited for each case, there may be some overlap among the factors cited in the Table 3-2.

Table 3-2. **Most Frequently-Cited Driver Factors by Vehicle Type**
Fatal SVRD Crashes

Driver-Related Factors	All Vehicles		Passenger Vehicles		Combination-Unit Trucks	
	Cases	Percent	Cases	Percent	Cases	Percent
Driving Too Fast	7,114	50.5%	6,269	50.1%	97	33.6%
Inattentive	1,466	10.4%	1,303	10.4%	47	16.3%
Erratic/Reckless	1,287	9.1%	1,152	9.2%	19	6.6%
Drowsy, Asleep	987	7.0%	918	7.3%	44	15.2%
Over Correcting	815	5.8%	801	6.4%	10	3.5%
Homicide	681	4.8%	646	5.2%	7	2.4%
Other Improper Turn	534	3.8%	489	3.9%	13	4.5%
Drugs	366	2.6%	320	2.6%	8	2.8%
Water, Snow, Oil	321	2.3%	307	2.4%	9	3.1%
Failure To Obey	243	1.7%	201	1.6%	4	1.4%
Ill, Blackout	237	1.7%	231	1.8%	2	0.7%
Total Cases	14,100		12,514		289	

- **Obstruction of Driver Vision**

Obscuring of driver vision was noted very rarely -- only about 1.5 percent of SVRD crash vehicles (hit & run vehicles excluded). There was little difference between passenger vehicles and combination-unit trucks.

- **Critical Event**

Critical Event (V26, P_CRASH2) is a new GPS variable in the 1992 file. It is defined as follows:

> The event which made the crash imminent (i.e., something occurred which made the collision possible). A critical event is coded for each vehicle and identifies the circumstances leading to this vehicle's first impact in the crash.

In cases where more than one critical event is applicable (e,g., excessive speed ***and*** poor road conditions), the most significant critical event is coded.

The following SVRD critical events were notable based on 1992 GES data. Unless otherwise noted, all percentages are for all vehicle types combined:

- Traveling over right edge of roadway -- 29.2 percent
- Traveling over left edge of roadway -- 15.2 percent
- Traveling over unknown edge of roadway -- 2.4 percent
- End departure -- 1.6 percent
- Excessive speed -- 9.6 percent overall; percentages by vehicle type:
  - Passenger vehicles: 9.8 percent
  - Combination-unit trucks: 4.6 percent
- Poor road conditions -- 8.6 percent
- Blowout/flat tire -- 1.3 percent
- [Other] disabling or minor vehicle failure -- 1.7 percent
- Critical event initiated by another vehicle (total of 20 specific subtypes) -- 8.3 percent
- Critical event initiated by pedestrian, pedalcyclist, other nonmotorist, or animal (total of 10 specific subtypes) -- 3.2 percent.
- Miscellaneous/other (several subcategories) -- 18.9 percent.

- **Corrective Action Attempted**

Corrective Action Attempted (V27, P_CRASH3) is another new GES variable in the 1992 file. It is defmed as the "actions taken by the driver of this vehicle in response to the impending danger."

The following SVRD corrective actions attempted were notable based on 1992 GES data. All percentages are for all vehicle types combined:

- No corrective action attempted -- 66.8 percent
- Braked/slowed -- 8.8 percent
- Steered to left -- 4.3 percent
- Steered to right -- 5.8 percent
- Braked and steered -- 1.7 percent
- Other/unknown -- 12.6 percent

- **Vehicle Control After Corrective Action**

Vehicle Control After Corrective Action (V29, P-CRASH4) is another new GES variable in the 1992 file. It is defined as follows:

> The stability of the vehicle during the period immediately after the attempted corrective action, up to the initial impact in the crash sequence. The stability of the vehicle prior to corrective action is not considered.

The following vehicle control states after corrective actions were notable based on 1992 GES data. All percentages are for all vehicle types combined:

- No corrective action attempted -- 66.8 percent
- Vehicle slid/skid longitudinally -- 7.5 percent
- Vehicle control maintained -- 4. 1 percent
- Vehicle rotated (yawed) -- 3.8 percent
- Other/unknown -- 17.8 percent.

4. TRI-LEVEL STATISTICS ON CRASH CAUSES

This chapter uses the Indiana Tri-Level Study (See Appendix A, Item A.1.5) information to present possible causes for SVRD crashes. 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. 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.

As indicated in Chapter 3, rollover, vehicle collisions with fixed objects, and vehicle collisions with parked vehicles are three major first harmful events for SVRD crashes. Therefore, Indiana Tri-Level study (Treat et al, 1979) findings on the causal factors associated with 153 identified SVRD crashes are organized into these three categories. There were 37 rollover cases (CARDfile Accident Type llO), 95 crashes into stationary objects (CARDfile Accident Type 111) and 21 collisions with parked vehicles (CARDfile Accident Type 113). In the study, multiple crash causes were often indicated in three major categories: vehicular factors, human causes, and environment causes. Causal factors cited as "certain" or "probable" are listed below. Statistics are presented separately for single vehicle rollover, SVRD into stationary object and collisions with parked vehicles.

Single Vehicle Rollover (37 cases, 9 percent of all in-depth Tri-Level crashes):

- **Vehicular factors** (9 cases, 24 percent)

- **Human causes (35** cases, 95 percent)

  Direct human causes (35 cases, 95 percent)

    Recognition errors (10 cases, 27 percent)
      Recognition delays - reasons identified (8 cases, 22 percent)
        Inattention (5 cases, 14 percent)

    Decision errors (25 cases, 68 percent)
      Improper Driving Technique (4 cases, 11 percent)
      Excessive speed (15 cases, 41 percent)
        For road design - regardless of condition or traffic (11 cases, 30 percent)
      Improper evasive action (8 cases, 22 percent)

Performance errors (12 cases, 32 percent)
Overcompensation (9 cases, 24 percent)
Inadequate directional control (6 cases, 16 percent)
On straight, curve-vehicle off road edge (5 cases, 14 percent)

Indirect human causes (6, 16 percent)
Experience or exposure (5 cases, 14 percent)

- **Environmental causes** (18 cases, 49 percent)

Environmental causes - slick roads (5 cases, 14 percent)

Environmental causes - except slick roads (14 cases, 38 percent)

Highway-related causes (12 cases; 32 percent)
Control hindrances (6 cases, 16 percent)
Inadequate signs and signals (4 cases, 11 percent)
Design problems (7 cases, 19 percent)
Road overly narrow, twisting, etc. (6 cases, 16 percent)

Ambience related causes (4 cases, 11 percent)

SVRD Collisions with Stationary Objects (95 cases, 23 percent of all in-depth Tri-Level crashes):

- **Vehicular factors** (17 cases, 18 percent)
  . Brake system (9 cases, 9 percent)

- **Human causes** (82 cases, 86 percent)

Direct human causes (81 cases, 85 percent)

Recognition errors (19 cases, 20 percent)
Recognition delays - reasons identified (12 cases, 13 percent)
Internal distraction (8 cases, 8 percent)

Decision errors (55 cases, 58 percent)
Excessive speed (32 cases, 34 percent)
For road design - regardless of condition or traffic (17 cases, 18 percent)
Improper evasive action (17 cases, 18 percent)

Performance errors (21 cases, 22 percent)
Overcompensation (13 cases, 14 percent)

Indirect human causes (21, 22 percent)
Physical or physiological (17 cases, 18 percent)
Alcohol Impairment (9 cases, 9 percent)

- **Environmental causes** (32 cases, 34 percent)

Environmental causes - slick roads (12 cases, 13 percent)

Environmental causes - except slick roads (22 cases, 23 percent)
Highway-related causes (12 cases, 13 percent)
Ambience-related causes (14 cases, 15 percent)
Special hazards (10 cases, 11 percent)
Non-contact vehicle caused problem (8 cases, 8 percent)

SVRD Collisions with Parked Vehicles (21 cases, 5 percent of all in-depth Tri-Level crashes):

- **Vehicular factors** (5 cases, 24 percent)

Tire and wheels (2 cases, 10 percent)
Inadequate tread depth (2 cases, 10 percent)

. Communication system (2 cases, 10 percent)
Vehicle-related vision obstructions (2 cases, 10 percent)
Window-Ice, snow, frost, water (2 cases, 10 percent)

- **Human causes** (17 cases, 81 percent)

Direct human causes (17 cases, 81 percent)

Recognition errors (10 cases, 48 percent)
Recognition delays - reasons identified (10 cases, 48 percent)
Inattention (3 cases, 14 percent)
Position of car on road (2 cases, 10 percent)
Internal distraction (2 cases, 10 percent)
Event in car; e.g., sudden noise (2 cases, 10 percent)
External distraction (2 cases, 10 percent)
Improper lookout (3 cases, 14 percent)

Decision errors (11 cases, 52 percent)
Misjudgment-distance, closure rate (2 cases, 10 percent)
Improper driving technique (3 cases, 14 percent)
Improper evasive action (4 cases, 19 percent)
Locked brakes, couldn’t steer, tired (2 cases, 10 percent)

Indirect human causes (2 cases, 10 percent)

- **Environmental causes** (9 cases, 43 percent)

  Environmental causes - slick roads (3 cases, 13 percent)

  Environmental causes - except slick roads (7 cases, 33 percent)
  Highway-related causes (2 cases, 10 percent)
  Ambience-related causes (5 cases, 24 percent)
  Special hazards (4 cases, 19 percent)

The Tri-Level frequency and percentage analysis suggest that SVRD crashes result largely from driver decision errors, such as excessive speed. Other direct human causes, indirect human causes (e.g. alcohol), and environmental factors also are common factors in SVRD crashes. This pattern is true for all three SVRD crash subtypes.

More recent analyses of SVRD crash scenarios (e.g. Mironer et al, 1994) indicate a variety of causal factors with no single factor predominating. Causal factor frequently cited include excessive speed/reckless maneuvers, slippery roads, driver inattention/distraction, evasive maneuver to avoid other crash (e.g. with animal, pedestrian, or other vehicle), driver drowsiness, and driver intoxication.

APPENDIX A: PROBLEM SIZE AND DESCRIPTIVE STATISTICS

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

A.1 Crash Datafiles and Other Information Sources Accessed

The following data sources have been used to estimate single vehicle roadway departure and "all crashes" problem size and descriptive statistics:

AS.1 NHTSA General Estimates System (GES)

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

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

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

A.1.2 NHTSA Fatal Accident Reporting System (FARS)

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

A.1.3 NHTSA NASS Continuous Sampling Subsystem (CSS)

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

AS.4 NHTSA NASS Crashworthiness Data System (CDS)

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

CDS data are not cited in this report, but have been used as part of the related single vehicle roadway departure “problem definition/countermeasure technology assessment” program described in Chapter 1.

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

The Indiana Tri-Level Study (Treat et al, 1979a), was an in-depth study of crash 'causes conducted in the late 1970s by Indiana University. The term "Tri-Level" referred to the collection of three qualitatively-different types of data: mass data (e.g., driver license data including past violations),-on-scene crash data (e.g., driver interviews, photography of skidmarks and vehicle final rest positions), and follow-up reconstructions, which included a consideration of human, vehicle, and environmental factors contributing to the crash. Although the study sample size was small (i.e., 420 in-depth cases) and geographically 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 sizes, but will be used to provide insights on causes of crash types. Applicable statistics from the Tri-Level Study are cited in the narrative text of this report; detailed statistical summaries from the study have been prepared as separate documents.

A.1.6 FHWA Statistics on Registration, Mileage, and Driver Licenses

Statistics on vehicle registrations and vehicle miles traveled (VMT) were obtained from the Federal Highway Administration (FHWA) publication Highway Statistics 1991 (FHWA-PL-92-025). Table VM-1 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. In addition, driver age and sex involvement patterns were calculated for 1990 using two different statistical metrics: rate (per 100 million VMT) and likelihood (involvements per 1,000 registered drivers). The number of licensed drivers for various age and sex groups was obtained from Table DL-22 of Highway Statistics 1990 (FHWA-PL-91-003).

A.2 Statistical Measures of Problem Size

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

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

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

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

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

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

Explanation: FARS statistics are preferred, since FARS provides a count of fatalities, as opposed to an estimate. FARS statistics are used for the single vehicle roadway departure 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 pedalcychsts 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 single vehicle roadway departure 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 their total effect on society.

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

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

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

"FATAL EQUIVALENTS" CRASH SEVERITY SCALE		
Crash Severity (Most severely-injured occupant, KABCO)	**Comprehensive $ Value Per Crash (1988 Dollars, 4% Discount Rate)**	**Fatal Crash Equivalent ("FCE")**
Fatality (K,4)	$2,722,548	1.0000
Incapacitating (A,3)	$228,568	0.0840
Non-incapacitating (B,2)	$48,333	0.0178
Possible (C, 1)	$25,228	0.0093
No Injury (0,O)	$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: These statistics relate 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, SVRD represent a high percentage of crashes, crash FCEs, and fatalities.

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

6. Involvement Rate Per 100 Million Vehicle Miles Traveled

Calculated from target PR crashes and VMT

Explanation: Involvement rates per 100 million vehicle miles traveled are calculated from annual target crash estimates and annual VMT estimates (see Table A-2 below). When the problem is defined for a particular vehicle role (e.g., lane changing/merging vehicle in a lane change/merge crash or backing vehicle in the backing crashes), 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 single vehicle roadway departure crashes. 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: 1990 AND 1991 VEHICLE MILES TRAVELED (IN MILLIONS) FOR VARIOUS VEHICLE CATEGORIES

(Source: Highway Statistics, 1991, FHWA, Table VM-1)

ANNUAL VEHICLE MILES TRAVELED (**VMT,** in millions)		
Vehicle Category: 1990 1991		
All Vehicle Types	2,147,501	2,172,214
Passenger Vehicles	1,982,197	2,006,553
Combination-Unit Trucks	96,482	96,949
Single-Unit Trucks	53,522	53,791
Motorcycles	**9,557**	**9,178**

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

- All vehicle types: 11,281 miles
- Passenger vehicles: 11,032 miles
- Combination-unit trucks: 60,429 miles
- Single-unit trucks: 12,656 miles.
- Motorcycles: 2,197 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 single vehicle roadway departure crashes) or based upon a particular vehicle role in the crash (e.g., lane changing/merging vehicle in lane change/merge crash). Note that the passenger vehicle registration data in Table A-3 includes both passenger cars ***and*** 2-axle, 4-tire single-unit trucks (i.e., pickup and vans). The single-unit truck data shown does nor include 2-axle, 4-tire trucks and thus corresponds to the "Other Single-Unit Trucks" column of Table VM-1 of Highway Statistics.

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

VEHICLE REGISTRATIONS		
Vehicle Category:	1990	1991
All Vehicle Types	195,914,924	192,548,972
Passenger Vehicles	182,201,372	181,885,983
Combination-Unit Trucks	1,607,183	1,604,335
Single-Unit Trucks	4,219,920	4,250,338
Motorcycles	4,259,462	4,177,037

8. Expected Number of Involvements During Vehicle Life

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

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

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

Like the previous two statistics, this statistic may be calculated based on all involvements (e.g., all crashes, all single vehicle roadway departure crashes) or based upon a. particular vehicle role in the crash (e.g., lane changing/merging vehicle in lane change/merge crash). For specific crash types (and especially for specific vehicle roles in specific crash types), this value is typically low; i.e., less than 0.2. For such low values, the statistic can be treated as ***an approximate probability*** — 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.
- Vehicle life, motorcycles: 7.5 (estimated from vehicle age data in Motorcycle Statistical Annual 1992).

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:

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

Statistical constants used to make these calculations include the following:

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

NPR crash problem size estimations resulting from the above algorithm should not be accepted uncritically. The algorithm assumes proportionality between NPR crashes and PR PDO crashes, which are generally more severe than NPR crashes. The algorithm likely overestimates NPR crashes for crash types that are often serious and thus not likely to go unreported. Examples include head-on crashes and rollovers. On the other hand, the algorithm likely underestimates NPR crashes for crash types that are usually minor in severity and thus less likely to be reported. Examples include rear-end crashes and backing crashes. Single vehicle crashes is general may be less likely to be reported to police, since there is no "not at fault" driver with an incentive to report the crash to police to ensure prosecution and/or liability compensation. As this program progresses, it may be possible to develop a more sophisticated NPR crash estimation algorithm or to incorporate fmdings from other sources (e.g., insurance claim data) to better estimate NPR crashes.

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

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

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

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

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

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

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

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

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

11. Estimated Annual Vehicle-Hours of Crash-Caused Delay

Estimated from calculations based on . UDH vs. Non-UDH breakout

Percent of All Crash-Caused Delay

Delay caused by the target crash type as a percentage of all crash-caused delay (estimated here as 450.2 million vehicle hours for 1991).

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

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

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

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

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

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

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

A.3 Descriptive Statistics

In addition to problem size assessment statistics, this document provides descriptive statistics relating to crash incidence. These are primarily univariate and bivariate (e.g., vehicle type category by other factor) distributions that characterize the component "subtypes" of the target crash type, conditions under which target crashes occur, and, when possible, statistics providing insights into the primary causes of crashes. The national crash databases described in Section 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.

For the sake of brevity, only the most relevant statistical findings are provided in this report. Comprehensive statistical printouts of these data retrievals have been provided directly to NHTSA and contractor personnel studying the SVRD crash problem.

A.4 Definitions of Vehicle Types

For most data retrievals (including the single vehicle roadway departure 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 and motorcycles.

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

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

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

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

01 ≤ Body Type ≤ 49

GES Combination-Unit Truck:

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

GES Single-Unit Truck:

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

GES Motorcycle:

70 ≤ Body Type ≤ 79

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

01 ≤ Body Type ≤ 49

FARS Combination-Unit Truck:

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

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

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

<u>FARS Motorcycle</u>:

80 </= Body Type </= 89

APPENDIX B: PROBLEM SIZE ASSESSMENT: ALL CRASHES

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

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

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

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

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

Statistic	1990	1991
Police-Reported Crashes (GES)	6.46 million	6.11 million
Vehicles Involved in Police-Reported Crashes (GES)	11.3 million	10.7 million
Fatali ties (FARS)	**44,599**	41,508
Non-Fatal Injuries in PR Crashes (GES)	3.33 million	3.10 million
Non-Police Reported Crashes (Miller, 1991)	7.77 million*	7.77 million*
Urban Divided Highway Crashes (PR+NPR; see Chpt 2 for Estimation Method)	2.23 million	2.22 million
Crash-Caused Vehicle-Hours Delay (PR+NPR; see Chpt 2 for Estimaion Method)	460.2 million hours	450.2 million hours

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

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

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

This apparent paradox is due to the much greater crash ***exposure*** of trucks; i.e., their average annual vehicle miles traveled is approximately six times that of passenger vehicles. In addition, combination-unit truck crashes are more likely to be severe; in 1991 there were approximately 19.1 fatalities per 1,000 police-reported truck crashes, versus approximately 6.3 fatalities per 1,000 police-reported passenger vehicle crashes.

The greater likelihood of truck involvement in crashes, together with the greater average severity of these crashes, makes combination-unit trucks an attractive test bed for crash avoidance countermeasures.

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

GES/FARS-Based Statistics (1991)		All Vehicles	Passenger Vehicles	Combiition-Unit Trucks	Single-Unit Trucks	Motorcycles
Annual # PR Crashes (GES)	Total:	6,110,OOO	5.966.000	190,000	130,000	~103,000
	Injury:	2,037,000	1.981,000	45,000	34,000	79,000
	PDO:	4,073,000	3.985.000	146,000	96,000	25,000
Annual # Fatalities (FARS)		41,508	38.173	3,642	1.162	2,933
Am. # Non-Fatal PR Injuries (GES)	**Total:**	**3,097,000**	3.027.000	63,000	48,000	92,000
	A:	442,000	425,000	14,000	7,000	25,000
	B:	879,000	846,000	19,000	13,000	42,000
	c:	1,775,000	1.757,000	30,000	28,000	24.000
Fatal Crash Equivalents (FCEs)		91,827	. 86,533	4,492	1,964	5,635
Involvement Rate Per 100 Million VMT		493.1	508.6	204.4	244.2	l,135.4
Annual Involvements Per 1,000 Registered Vehicle3		55.63	56.11	123.51	30.90	24.93
Expected ##Involvements During Vehicle Life		0.7304	0.7299	1.8157	0.4543	0.1870
Estimated Annual # NPR Crashes	Total:	7,770,000	7,603,000	278,000	183,000	47,000
	Injury:	917,000	897,000	33,000	22,000	6,000
	PDO:	6.853.000	6.706.000	245,000	161,000	41.000
Estimated Total Annual Crashes (PR + NPR)	Total:	13,880.OOO	13.569,000	468.000	313,000	150.000
	UDH:	2,223,OOO	2,180,OOO	144,000	51.000	18,000
	Non-UDH:	11,657,OOO	11,389,000	324,000	262,000	132,000
Crash-Caused Congestion (Delay)	Veh-Hours:	450.2 M	441.1 M	27.0 M	10.0 M	4.9 M

Legend:

A	Incapacitating Injuries	M	Million
B	Nonincapacitating Injuries	NPR	Non-Police Reported
C	Possible Injuries	PDO	Property Damage Only
FAR8	Fatal Accident Reporting System	PR	Police Reported
FCE	Fatal Crash Equivalent	UDH	Urban Divided Highway
GES	Gcneral Estimates System	VMT	Vehicle Miles Travel

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

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

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

As noted in Appendix A, the statistics provided for non-police-reported (NPR) crashes, urban divided highway crashes (PR+NPR) and crash-caused delay are based on new estimation techniques that have not been verified. Thus, they should be regarded as very rough estimates. Although these statistics are rough, they will be useful in comparing difficult-to-quantiy 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 SVRD 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.

PPENDIX C: GENERALIZED ESTIMATED SAMPLING ERRORS FOR 1991 GES

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

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

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

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

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

TABLE C-1:

1991 CRASH ESTIMATES AND STANDARD ERRORS

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

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

$$a=9.93401$$

$$b=0.06362$$

TABLE C-2:

1991 VEHICLE ESTIMATES AND STANDARD ERRORS

Estimate (x)	One Standard Error (SE)*	Estimate (x)	One Standard Error (SE)*
1,000	400	600,000	39,900
5,000	1,000	700,000	46,100
10,000	1,600	800,000	52,200
20,000	2,500	900,000	58,400
30,000	3,400	1,000,000	64,700
40,000	4,200	2,000,000	128,300
50,000	4,900	3,000,000	194,500
60,000	5,700	4,000,000	263,100
70,000	6,400	5,000,000	334,000
80,000	7,100	6,000,000	406,900
90,000	7,800	7,000,000	481,600
100,000	8,500	8,000,000	558,200
200,000	15,000	9,000,000	636,400
300,000	21,300	10,000,000	716,100
400,000	27,500	11,000,000	797,400
500,000	33,700	12,000,000	880,100

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

TABLE C-3:

1991 PERSON ESTIMATES AND STANDARD ERRORS

Estimate	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

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