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Accident Data Analysis of Side-Impact, Fixed Object Collisions

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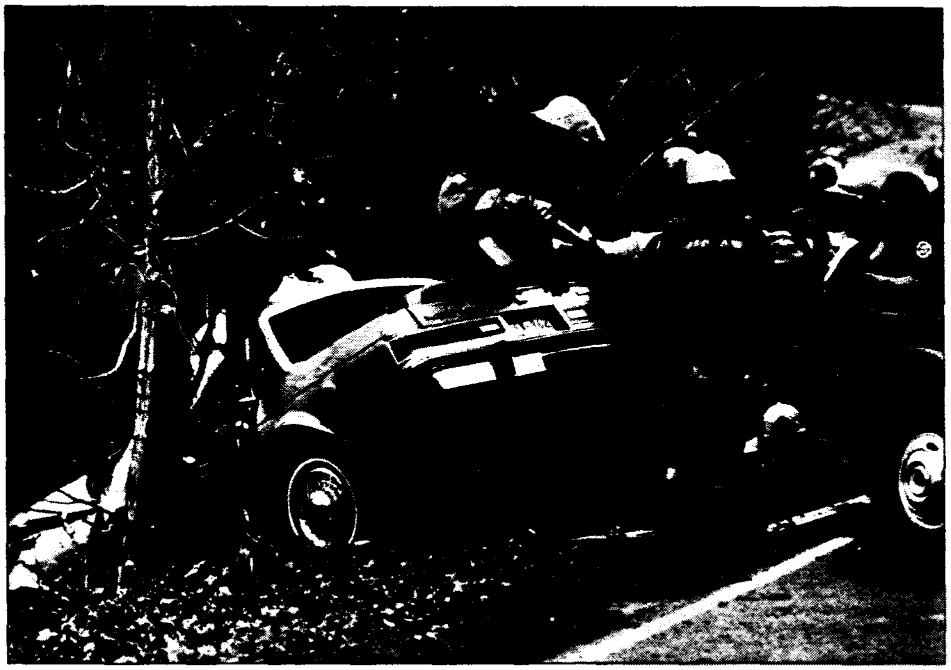

U.S. Department of Transportation
Federal Highway Administration

Research and Development
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FOREWORD

This report documents a study to investigate the causes and severity of side impact collisions with fixed roadside objects such as trees, utility poles, and guardrails. This report is one of three that address various aspects of side impact collisions. The first report, *Accident Data Analysis of Side-Impact Fixed Object Collisions* (FHWA-RD-91-122), presents the results of an analysis of the Fatal Accident Reporting System (FARS) and National Accident Sampling System (NASS) accident data bases. The second report, *Side-Impact Test and Evaluation Procedures for Roadside Structure Crash Tests* (FHWA-RD-92-062), presents recommendations for performing side impact crash tests of roadside appurtenances. The third report in this series, *Side-Impact Crash Testing of Roadside Structures* (FHWA-RD-92-079), presents the results of a side-impact crash-testing program involving luminaire supports and guardrail terminals.

This report (FHWA-RD-91-122) describes an investigation of National Accident Sampling System (NASS) and Fatal Accident Reporting System (FARS) data. The analysis explored the characteristics of side-impact collisions involving fixed objects along the roadside. The report examines the types of fixed objects struck, the types of injuries that occur in such collisions, and the characteristics of the sites and the characteristics of occupants.

This report will be of interest to practicing engineers with responsibility for managing the safety of the roadside as well as researchers and agencies involved in performing and evaluating roadside, appurtenance crash tests.

Lyle Saxton

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Operations Research and Development

NOTICE

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16. Abstract

The results of a study of accident data on side-impact, fixed-object collisions are presented in this report. The Fatal Accident Reporting System (FARS) was used to determine basic characteristics of this type of collision such as seating position of fatally injured occupants, roadway type, surface conditions, and vehicle weights. The National Accident Sampling System (NASS) was used to examine these same characteristics for accidents of all severities. In addition, the effects of breakaway objects, guardrails, and impact conditions on these collisions were examined using the NASS data. Characteristics of side-impact, fixed-object accidents such as location of impact, body region injured, injury sources, deformation measurements, occupant age, and time of day were also investigated using the NASS data. The characteristics of fixed-object, side impacts were then compared to those of vehicle-to-vehicle side impacts.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

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

MASS

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C

ILLUMINATION

Symbol	When You Know	Multiply By	To Find	Symbol
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

FORCE and PRESSURE or STRESS

Symbol	When You Know	Multiply By	To Find	Symbol
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

MASS

Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F

ILLUMINATION

Symbol	When You Know	Multiply By	To Find	Symbol
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl

FORCE and PRESSURE or STRESS

Symbol	When You Know	Multiply By	To Find	Symbol
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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1 INTRODUCTION

Every year approximately 225,000 people are involved in side-impact collisions with fixed roadside objects. One in three is injured and 1 in 100 is killed. Passenger-vehicle, side-impacts are dangerous because they often occur at a location on the vehicle that provides little protection to the occupant. The distance between the occupant and the object struck is at a minimum on the side; although doors are sometimes reinforced, the window offers no protection for the head. In addition, seat belts offer little resistance in the lateral direction. Because the distance between the occupant and the impacted object is small in lateral collisions, impacts with fixed roadside objects, especially narrow ones, are likely to result in serious injury. Fixed objects include natural features such as trees and shrubs and man-made features such as luminaires, sign posts, and longitudinal barriers. This report explores the characteristics of side impact accidents with fixed roadside objects.

In the early 1970's researchers found that side impacts were a significant enough problem to warrant improvement in vehicle occupant side protection. Federal Motor Vehicle Safety Standard (FMVSS) 214 was developed which required that all automobiles sold in the United States after January 1, 1973 would be required to meet a minimum door strength. Research in the late 1970's showed that this standard had indeed been effective in reducing injury, but that, after frontal collisions, side-impacts were still the next leading type of fatal automobile collisions.[1]

Fixed-object collisions are a dangerous type of collision, but they appear to be the type of side-impact with the most potential for improvement. Mak and Mason note that fixed-object accidents are 2.2 times more likely to result in a fatality than all other types of accidents combined.[2] A study in the United Kingdom determined that, of all types of side-impacts, the most effective countermeasures for protecting occupants in 48 percent of the struck-side fatalities were road design changes such as protecting roadside objects.[3] These countermeasures were also found to be the most effective countermeasures in 35 percent of the opposite-side fatalities. This seems to indicate that protecting occupants from fixed-objects has more potential for improving the side-impact problem than some other types of improvements.

Improving side-impact performance, however, has proven to be very difficult, prompting some to suggest abandoning the effort altogether. Huelke concludes, "There is little justification in these data for the extensive side collision research and testing for occupant protection in passenger compartment impacts."[4] The data he refers to, however, combined vehicle-to-vehicle side impacts with vehicle-to-fixed-object side impacts. Indeed, combining these two types of collisions does lead to conclusions that appear to defy logic. Separation of the two, however, can lead to a better understanding of both.

Although three-fourths of the side-impact collisions are vehicle-to-vehicle, side impacts with fixed roadside objects are a significant safety problem.[5] In a French study of this type

Table 1. Injury severity versus struck object in side-impact collisions. [6]

Occupant Injuries	Obstacles					
	Other Vehicles		Fixed Obstacles		Other	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
None	102	23	7	8	12	22
Minor/Moderate	239	55	38	41	34	62
Serious/Severe/ Critical	62	14	29	31	5	9
Unsurvivable	33	8	19	20	4	7
Total	436	100	93	100	55	100

of impact, Hartemann noted that although side-impact collisions with fixed objects are four times less likely to happen than side-impact collisions with other vehicles, fixed-object collisions are involved in 34 percent of side-impact fatalities.[6] Table 1, taken from the same study by Hartemann, shows a comparison of injury severity with type of object struck in side-impact collisions. This table shows that most of the vehicle-to-vehicle collisions resulted in low severity injuries, while the vehicle-to-fixed object collisions resulted in more serious injuries. Of the occupants whose vehicles struck fixed objects, 51 percent sustained critical to unsurvivable injuries; of those occupants who were struck by another vehicle, only 22 percent sustained injuries of this severity. In an analysis of collisions with breakaway and nonbreakaway poles, Mak and Mason note that only 25 percent of the accidents were side impacts, but they accounted for all but one of the fatalities.[2] Side impacts also accounted for more severe injuries than frontal or rear impacts.

Several researchers have hypothesized why fixed-objects collisions are so harmful. One aspect that affects the severity of injury is the location of impact. Hartemann's European study showed that most of the severe and fatal cases were located very close to the vehicle occupant, as indicated in figure 1.[6] The severe and fatal cases were grouped closer to the occupant seating position than cases of all severities. Lozzi, studying Australian pole accidents, found that occupants were only injured if the location of impact was adjacent to the vehicle occupant:[7]

> It can be stated that only those occupants whose head or torso had been disturbed by the pole or by car body components backed by the pole, have died. Others who may have been thrown against the inner boundaries of the car, and had their living space reduced greatly, did not die and, as pointed out above, were seldom injured. This observation implies that the mean accelerations involved in these types of impacts were generally low, and that only those occupants confronted by the fast hard intrusion of the pole itself were endangered.[7]

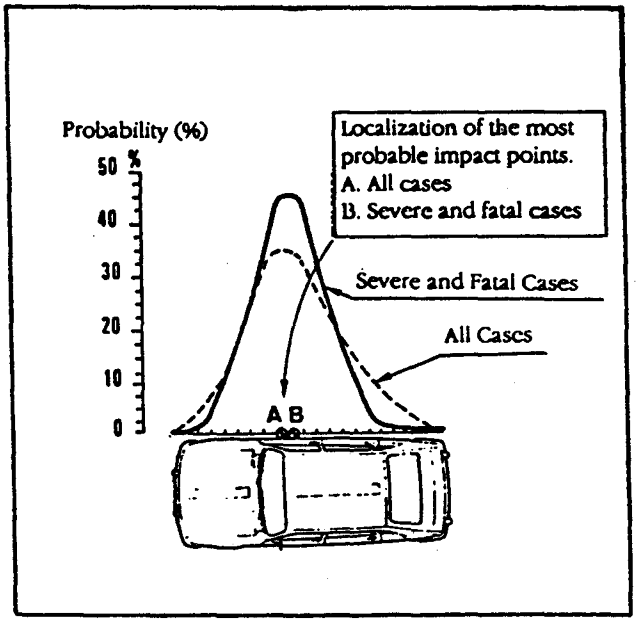


Figure 1. Location of impact in fixed-object, side-impact collisions. [6]

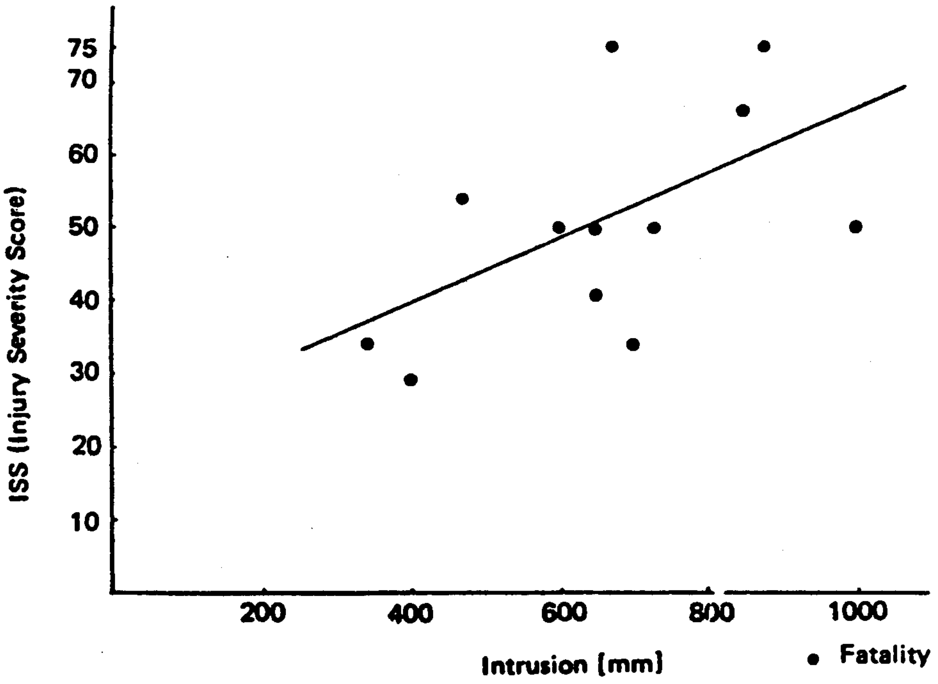


Figure 2. Intrusion versus ISS in fatal fixed-object, side-impact collisions. [7]

Another factor appeared to be necessary for fatalities in Lozzi's study – intrusion. It was difficult, however, for Lozzi to find a correlation between the magnitude of intrusion and injury severity. Figure 2 shows amount of intrusion versus the Injury Severity Score (ISS) score (a measure of injury severity) from the same study. Only those occupants who were fatally injured are represented in this figure, because there were very few survivors in this study. Although there appears to be a positive correlation between intrusion and ISS, the statistical significance of the line is less than 90 percent. In fact, "for pole impacts, quite unlike car-to car crashes, shallow intrusion did not imply slight injury."[7] Fixed object collisions do not appear to require deep intrusion to cause serious or fatal injuries.

Intuitively, change in velocity upon impact should have a similar effect upon injury as intrusion. Hartemann, et al., show that it is also difficult to find a correlation between velocity change and injury severity. Figure 3 shows a comparison of velocity changes in severe and fatal fixed-object, side-impact collisions with collisions of all severity.[6] The severe and fatal cases have slightly higher changes in velocity than cases of all severities, but once again the correlation is weak.

Two separate nationwide data bases were analyzed to explore the characteristics of side

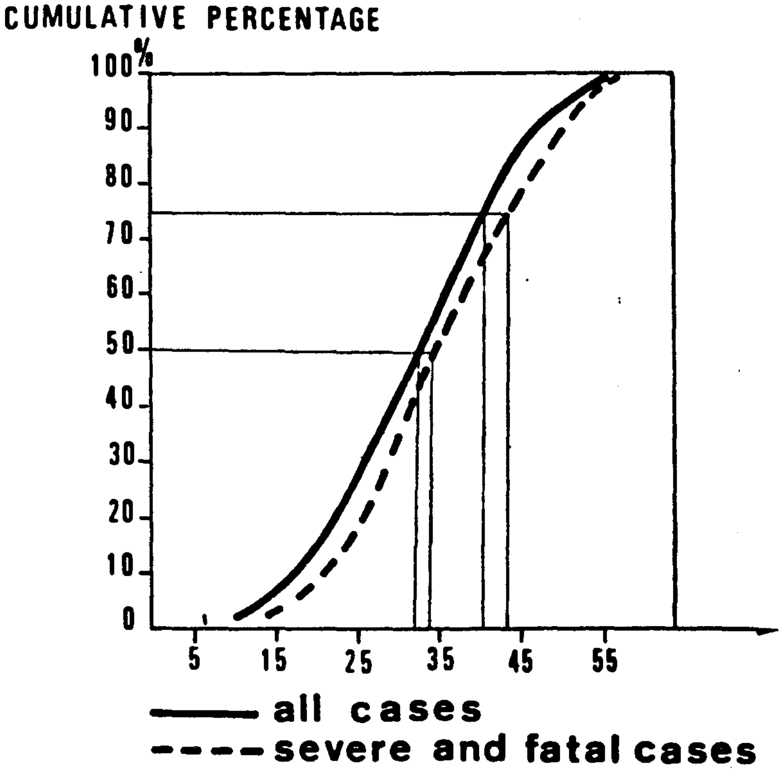


Figure 3. Change in velocity in fixed-object, side-impact collisions. [6]

impact collisions with fixed objects. The first, the Fatal Accident Reporting System (FARS), includes information on every motor vehicle accident involving at least one fatality. The National Accident Sampling System (NASS) Continuous Sampling System is a statistically based sampling of accidents of all severities.

Chapter 2 will discuss the details of each system. The FARS and NASS data will be used jointly to determine certain characteristics of side-impact, fixed-object collisions and then the NASS data will be used alone to ascertain information not available in FARS. Chapter 3 reviews and compares the information that can be found in both the FARS and NASS data bases. The chapter begins with information about the magnitude of the fixed-object accident problem, and then focuses on the magnitude of the side-impact, fixed-object collision problem. This chapter looks at the roadside objects that are responsible for the most injuries and deaths. It then goes on to determine the types of roadways where such collisions occur, the types of vehicles where passengers are most susceptible to injuries, and the effect of seating position. Finally, it investigates factors that surprisingly seem to have negligible effect on side-impact injuries. The fourth chapter includes results of analyses of the NASS data alone. This chapter looks at the different severities of occupant injury. The human body regions most often and most severely injured are investigated along with the sources of injury in the interior of the vehicle. It investigates the correlation between the extent and location of deformation with severity of injury. The impact conditions (i.e. change in velocity, angle of impact) are also discussed. Chapter 5 includes a discussion of how side-impact accidents with fixed objects differ from side-impact collisions with other vehicles. A summary of the data analysis is presented in chapter 6.

2 DATA SOURCES

The Fatal Accident Reporting System (FARS) and the National Accident Sampling System Continuous Sampling System (NASS) data bases were both used in the study of side-impact, fixed-object accidents. The FARS and the NASS differ from each other both in content and structure. Each has characteristics which make it useful in this study. This chapter explains the data collection methods in each, the characteristics of each, and the applications of each to the study of side-impact, fixed-object accidents.

FATAL ACCIDENT REPORTING SYSTEM

The FARS data contain details about nearly every reported motor vehicle accident in the United States that involved at least one fatality. The National Highway Traffic and Safety Administration (NHTSA) compiles the data from State records which contain information obtained from police reports. Roughly 250 variables are coded for more than 40,000 accidents each year. The years used in this study are 1980 through 1985. Data prior to 1980 is considered inconsistent with later years due to the increased use of smaller automobiles. To provide consistency with the NASS data, post-1985 FARS data was not used. Also, this study began in 1988 and at that time the data for years after 1985 was not immediately available. All the FARS values in this report refer to the average yearly number of occupants fatally injured in motor vehicle collisions.

One of the primary advantages of using the FARS data is the large number of recorded accidents it contains. The FARS data is essentially the population of all fatal accidents. This large number of records makes this data base useful for obtaining a general overview of the magnitude of the side-impact, fixed-object problem which makes it useful for comparing side-impact accidents with other types of collisions. It is also valuable for determining which roadside objects are most often responsible for fatalities. It contains information on the size and weight of the vehicle and also on the seating location of the people that were killed.

Although the FARS data is sufficient for general purposes, the data is not detailed enough to determine many characteristics of an accident. The FARS data is limited to the information contained in the pole accident report. If there is a collision with more than one object in an accident, the information is not detailed enough to determine the sequence of events. Although the data makes a judgement on which event in a collision is the most harmful, it is impossible to determine in which event the injuries occurred. Also, because the information is obtained from police records, it may contain inconsistencies due to the variety of methods of recording information from State to State and investigator to investigator.

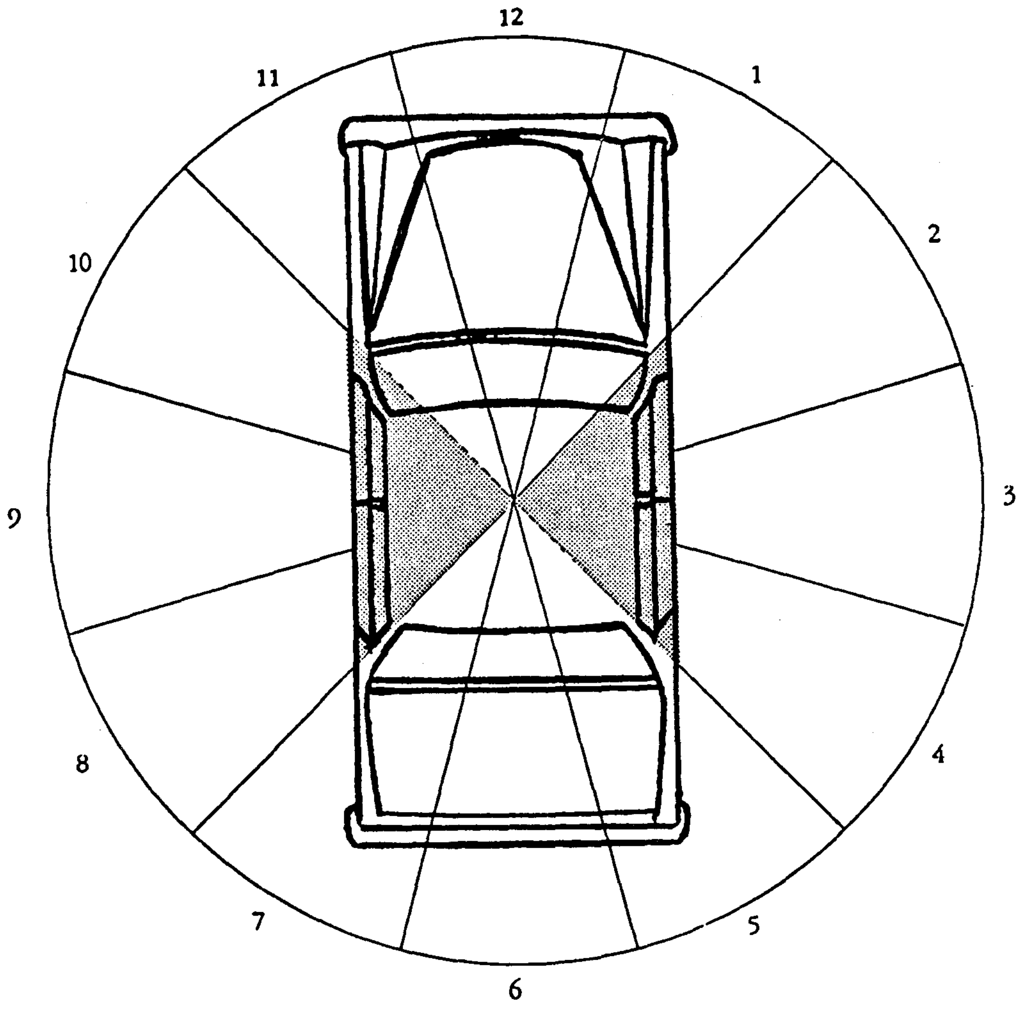


Figure 4. Clock direction used in FARS for location of impact.

In order to fully understand the information obtained from the FARS data base, it is necessary to understand the coding for some of the variables. The impact direction variables are coded as clock directions (30 degree increments). As shown in figure 4, the center of the clock corresponds to the center of gravity of the vehicle. A LOCATION-OF-IMPACT coded 12, indicates a frontal collision. In this study, side impacts were considered to be those collisions where the impact occurred primarily between clock directions 2 and 4, or 8 and 10 – the shaded areas in figure 4. In other words, side impacts are those accidents in which the worst vehicle damage occurred between 45 and 135 degrees from the longitudinal axis – at or near the passenger compartment. It should be noted that some "side impacts" – those occurring at clock directions 1, 5, 7 and 11 – are not included in this study. These types of collisions are usually considered frontal oblique collisions (1 and 11) or rear end collisions (5 and 7).

The other data variables that need explanation are the MOST-HARMFUL-EVENT and the FIRST-HARMFUL-EVENT. Both of these variables indicate objects that were involved in the accident. The FIRST-HARMFUL EVENT is the first collision event in the accident whereas the MOST-HARMFUL-EVENT is the event that caused the greatest injury. For example, suppose a car sideswiped another car, ran along a guardrail and then struck a tree. The FIRST-HARMFUL-EVENT variable would be coded as another vehicle. If the tree caused the most damage to the vehicle, then the MOST-HARMFUL-EVENT would be coded as a tree. Since this investigation is dealing with fixed objects, only those accidents whose MOST-HARMFUL-EVENT is a fixed object are used.

NATIONAL ACCIDENT SAMPLING SYSTEM

To investigate injury severity and occupant involvement in side-impact collisions, the 1982 through 1985 NASS data were used. The NASS coding and sampling techniques have varied from year to year, but were thought to be most stable in the 4 years chosen. As with the FARS, the quality of the data depends on the skill of the data collector and other factors discussed below. Side impacts were identified using a variable that identifies the location of the most severe impact. When this variable was coded left or right side, that accident was included in the study.

Unlike the FARS, the NASS data are a *sample* of all accidents in the United States in a given year. The sampling method involves several steps. First, the entire United States is divided into geographical units. No more than 50 of the over 1,000 geographical units are chosen for use in the NASS data to represent the accident population in all of the geographical units in a year. The units where a sample is taken are called primary sampling units (PSU's). The selection of these PSU's is based on characteristics such as geography, urbanization, per-capita gas station sales, and per-capita road miles. The actual sample, then, is built using less than 5 percent of the possible geographic units. Within each PSU, all of the police agencies were categorized by the type and number of accidents reported to the police. A small number of police agencies were then selected randomly within each category. The accidents which were finally investigated were a small subset of all police reported accidents within those police agencies. These accidents were not chosen at random because the large number of property-damage-only accidents would limit the number of more interesting injury accidents that could be investigated. The accidents included in the NASS data, therefore, contain an overrepresentation of injury accidents. To eliminate this bias toward injury accidents, an inflation factor is used such that, when the sampled number of each accident type is multiplied by this factor, it will represent the total number of that type of accident occurring within that PSU. In order to obtain national estimates, the PSU estimates are then multiplied by an expansion factor based on the 1977 population of that PSU. Unless otherwise noted, the NASS data shown in this report are the national estimates of accidents.

As with any statistical sample, the confidence that can be placed in a particular estimate is a function of the size of the sample in relation to the population. When sample sizes are very small, as is the case with the NASS data, the analyst should realize that the *true* value may be quite different from the value obtained using the sample. The standard error is a statistical parameter that measures the possible variability of the data. Large standard errors will result in wider confidence intervals. Some of the samples in this study were small subsets of the accident population and some of the samples had a large number of missing variables. In these two cases, the "raw," or unextrapolated, NASS numbers were generally used. When the extrapolated numbers were used in this document, the "raw" NASS numbers were included in the appendix. The raw numbers in this report represent total number of occupants investigated over the 4-year study. The extrapolated numbers are yearly averages of the 4-year study.

Estimates of the standard errors are provided in NHTSA's yearly NASS summary reports.[8] These references provide the standard errors of estimates and percentages for the NASS data based on sampling variability. The standard errors of percentages are based on the national estimates of the number of accidents in the subgroup being studied. The standard errors of percentages for single-passenger-vehicle, side-impact, fixed-object accidents were computed based on a national estimate of 673,436 (168,359*4 years) accidents and used table I of appendix F of the 1985 NASS summary report.[8] Where sufficient data existed to calculate the 68 percent confidence interval, the interval is included in the tables shown in this report. When a smaller subset of accidents, such as passenger compartment collisions, was chosen, the estimates were too small to determine the confidence intervals. When the amount of data was too small to calculate the confidence interval, the frequency of the observations alone are shown without the percent. Data in these frequency-only tables should be understood to be anecdotal and to a degree speculative. On the other hand, the most probable value to be sampled is the mean so the data shown represents the best available estimate of the fixed-object, side-impact problem.

Another source of sampling error occurs when more than 1 data year is used. The PSU's from year to year remain essentially the same, so the data may not be independent from year to year. If the data is not independent, the covariance between years must be added to the variance before calculating confidence intervals. The NASS summary reports which discuss how to calculate the variance for a given year do not mention this source of error. At the time of the data analysis on this project this source of error was not mentioned in the NASS literature and was therefore not considered in calculating the confidence intervals. All the confidence intervals in this report consider only the sampling error within a year. The error associated with combining data years was not included in any of the confidence intervals in this report. However, it is probable that the magnitude of this covariance error does not significantly affect the results.

Despite the large standard errors associated with subsets of the NASS data, this data set was used because of the lack of better alternatives. The FARS data base is useful for studying fatal collisions, but does not provide the detailed information needed for this study. The NASS data provides the best available evidence for examining the total range of severity of accidents and for studying accident characteristics in-depth, though it cannot be used with the same degree of statistical confidence as the FARS data. There were basically three choices open to the authors in performing this study:

- Completely ignore the NASS data.
- Use the biased, uninflated counts.
- Use the unbiased, inflated estimates.

The first alternative was rejected because nothing is gained by completely ignoring the data. When possible, the second alternative was also rejected because using uninflated counts (i.e. not using the national estimates) would be seriously biased toward severe accidents and would not take advantage of any of the techniques employed by NHTSA to minimize sampling error and bias. The second alternative would have resulted in an interesting anecdotal set of data that could not be used to hypothesize about the national side-impact problem. The third alternative was chosen because it represents the best available estimate of the side-impact problem.

Two subsets of the NASS data, the Longitudinal Barrier Special Studies (LBSS) and the Luminaire/Sign Support Special Studies (LSSSS), contain more detailed information than the NASS does. These special studies are not statistically based samples and their only purpose in this study would be for illustrative examples of the accidents described. The LSSSS was never received, but the LBSS was reviewed for this purpose.

The NASS data set provides more detailed information than the FARS data set. In addition to containing information on accidents of all severities, the number of minor, serious, severe, and fatal injuries are included. The NASS data can thus be used to determine the average severity of specific types of collisions. Because the NASS data does include all types of injuries, it provides a more accurate picture of the cost to society of specific types of accidents.

A limitation of the NASS data base, as with the FARS, is the inability to positively determine which event in the accident caused which injury. There are variables that give the sequence of events and variables that list the events in order of severity, but none that attribute specific injuries to specific events. Another drawback to the NASS data is that some of the variables are not coded for many of the accidents. Most of these variables are related to impact conditions where presumably many of the measurements and judgements were difficult, if not impossible, to obtain.

The coding on many of the variables is quite different for the NASS than for the FARS. First, the coding of side-impact accidents is not by clock direction. A variable simply

Table 2. Definitions of police reported injury scores.

PRIS	Injury Outcome
O	No Injury
C	Possible Injury
B	Nonincapacitating Injury
A	Incapacitating Injury
K	Killed
U	Unknown

denotes on which side or end of the vehicle the most severe collision occurred. Another variable specifies the exact location of the impact on the side. It indicates whether the damage was distributed over a large area or localized in a small area.

Rather than two variables that indicate the first and most harmful events, the NASS data contains variables that define the four worst impacts in the accident and the sequence of the first four impacts. The types of objects that may be coded for these events are more detailed than the FARS. For example, FARS includes all guardrails as one type of object whereas NASS denotes five different types of guardrails.

Three measures of injury severity are used in the NASS data. Six different values for the police-reported injury score (PRIS) are taken from actual police reports. The codes used in these reports are defined in table 2. This variable gives a measure of the accident outcome.

The second injury-related variable, the Abbreviated Injury Score (AIS) measures injury rather than outcome. Outcome indicates the result of the occupant's injuries. Examples of outcomes are death, survival with incapacitating injuries, and survival with no injury. Injury refers to the damage to individual body regions and includes injuries such as broken bones and lacerations. The purpose of the AIS is to record how severely specific body regions are injured. It does not attempt to measure outcome. The AIS coding manual notes that outcomes such as blindness, hemorrhage, asphyxia, drowning and death are not coded. Instead, the AIS bases the injury severity on the following criteria: "energy dissipation, threat to life, permanent impairment, treatment period, and incidence."[9] These factors are used to evaluate the severity of the injury and assign the injury an AIS from 1 to 6. As shown in table 3, a score of 1 represents a minor injury and a 6 signifies a "maximum injury" that would have caused death within 1 year of the accident. All injuries are coded separately whether they apply to the same body region or not. Any score over 3 is considered severe. Some examples of AISs of 4 are brain exposure, lung contusion, and amputation of the leg above the knee. A pulmonary artery, coronary artery, or aorta laceration results in a score of 5, and AIS-6 injuries include a crushed skull or brain stem.

Table 3. Definitions of abbreviated injury scores.

AIS	Injury Severity
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum(Unsurvivable)
9	Unknown

Table 4. Percent of Police Reported Injury Scores (PRIS) corresponding to the indicated maximum AIS.

	MAIS			
PRIS	**0**	**1,2,or 3**	**Over 3**	**Unknown**
0	81	19	0	0
C	13	62	1	24
B	3	84	0	13
A	1	86	5	8
K	0	29	61	10
U	15	85	0	0

The five highest AIS's per occupant are recorded. The variable recording the highest AIS is called the Maximum Abbreviated Injury Score (MAIS). The MAIS represents the worst single injury to an occupant. Since an MAIS is for only one injury, it may not indicate the amount of trauma to the whole body. Table 4 shows a cross tabulation of the PRIS and the MAIS from the NASS data. Recall that the PRIS records outcome and the MAIS represents injury. From this table it can be seen that an MAIS is not a very good indicator of the outcome of the the accident. Only 61 percent of those killed had MAIS's greater than 3, and only 5 percent of those with incapacitating injuries had MAIS's greater than 3. If the severity of an accident were based on the MAIS, the results would often be misleading because an MAIS tends to underestimate the outcome of an accident, especially when the outcome is an incapacitating injury or death.

The PRIS is used in this study when outcome is important. It is used to determine the most dangerous types of fixed objects and the worst location of impact. The MAIS is used when injuries to specific areas of the body are being investigated.

3 COMPARISON OF THE NASS AND FARS DATA

A comparison of data from the NASS and FARS data sets will provide insight into the side-impact, fixed-object problem. The data is used in this chapter to compare the number of occupants involved in all side-impact, fixed-object accidents with the number of occupants fatally injured in this type of accident. An investigation of the FARS data and the corresponding NASS data will provide some of the basic characteristics of side-impact collisions with fixed objects.

The FARS data represents occupants who were fatally injured. The values from the NASS data represent an estimate of the number of occupants involved in side-impact, fixed-object accidents. The FARS data measures the fatal accident problem, while the NASS data measures exposure to all side impacts. Every occupant involved in the accident – injured or uninjured – is hypothetically included in the NASS data. The numbers used in the figures and tables of this report represent yearly averages of occupants, not vehicles or accidents.

ROADSIDE-SAFETY PROBLEM

Before judgements about the magnitude of the fixed-object, side-impact problem can be made, the magnitude of the roadside-safety problem in general should be determined. For the purpose of this report the roadside-safety problem is defined as all losses and injuries that involve a feature of the roadside whose performance could be improved by changing design, warranting, or maintenance practices.

Table 5 compares the magnitude of the roadside safety problem as represented in the FARS and NASS data bases. There is a philosophical difference in assessing the harmful events between the NASS and FARS data. In the NASS data all events are collision events with the exception of explosions, fires, and immersions. In the FARS data, the noncollision group of events has a much broader definition. This is most problematic when considering rollovers caused only by steep embankments. In the FARS data this is considered a noncollision overturn whereas in the NASS data it is considered a collision with the ground. This inconsistency shows up in table 5, where 44 percent of the the FARS roadside-safety problems are noncollision overturns and 28 percent of the NASS roadside-safety problems are collisions with the ground. The writers consider both categories roughly equivalent although some collisions with ditches and embankments in the NASS may also represent FARS-like noncollision overturns. Since the objective of this study is to learn about fixed-object side-impacts, both noncollision overturns in the FARS data and ground collisions in the NASS data were removed from the study sample.

Table 5 indicates that more than 900,000 vehicle occupants were involved in

Table 5. Occupants involved in single- or multiple-vehicle collisions with roadside object or feature.

Most Harmful	**1980-85 FARS**		**1982-85 NASS**	
Event	Frequency	Percent	Frequency	Percent †
Fixed Object	8,795	56	914,180	72 ± 3
Noncollision Overturn	7,020	44	-	-
Ground Collisions	-	-	357,107	28 ± 3
Pavement Irregularity	4	0	0	0
Total	15,819	100	1,271,287	100

† 68th percentile confidence interval.

fixed-object collisions each year and almost 9,000 of these occupants were fatally injured. Fixed-object collisions are certainly a serious roadside-safety problem, fatally injuring 1 of every 100 involved occupants.

Even recognizing the uncertainty in the definition of noncollision overturn statistics, it appears that this type of accident is also a serious safety problem. More than 7,000 vehicle occupants were fatally injured in noncollision overturns. Presumably many of these accidents were a consequence of steep side slopes that caused the errant vehicle to roll over. Table 5 indicates that the roadside-safety problem is on the order of 16,000 occupant fatalities and 1,250,000 involved occupants each year. Clearly, a great deal of human suffering is caused by roadside-feature accidents.

MAGNITUDE OF SIDE-IMPACT, FIXED-OBJECT PROBLEM

The motivation for studying side-impact, fixed-object accidents comes from observing the magnitude of this particular safety problem. Table 6 displays a comparison of location of impact on the vehicle for all fixed-object collisions. Frontal impacts occur most often and cause the most fatalities. Because frontal impacts are responsible for the most deaths, they are the most-often studied; however, side impacts also cause considerable loss to society. Each year over 200,000 people are involved in side-impact collisions with fixed objects and over 2,000 are killed. Twenty-five percent of the occupants involved in all fixed-object collisions (NASS) and 25 percent of the fixed object fatalities occurred in side-impact collisions. Using the NASS data as an estimate of the total number of occupants involved, approximately 1 of every 100 occupants involved in either frontal impacts or side impacts is fatally injured. When an occupant is exposed to a fixed-object collision, a side impact is at

Table 6. Location of impact in fixed-object collisions.

Impact Location	1980-85 FARS Frequency	Percent	1982-85 NASS Frequency	Percent †
Front	5,701	65	602,650	66 ± 2
Side	2,241	25	226,470	25 ± 3
Rear	168	2	27,135	3 ± 1
Other	685	8	57925	6 ± 2
Total	8,798	100	914,180	100

† 68th percentile confidence interval.

Table 7. Yearly societal costs of side-impact, fixed-object accidents (1986 dollars).

Accident Severity	Side-Impact Fixed-Object Accidents		
	Cost per Person($)	Number of Accidents	Societal Cost (x $1,000,000)
Property Damage Only	2,000	106,716	213.4
Injury	11,000	59,996	660
Fatality	1,500,000	1,647	2,470.5
TOTAL		168,359	3,343.9

least as dangerous as a frontal impact. Table 7 shows the dollar amounts that the Federal Highway Administration suggests for cost-benefit analyses of roadside accidents. Using these figures, the total cost to society of side-impact collisions is over 3 billion dollars.[10]

Some of the side-impact accidents in which the Most Harmful Event was a fixed object may have involved more than one vehicle. Since part of the purpose of this study is to determine how people are injured in side-impact accidents with fixed objects, it is advantageous to eliminate from the sample collisions that involve more than one vehicle. As shown in table 8, the NASS data indicate that 94 percent of the occupants involved in side-impact, fixed-object collisions were in vehicles that did not strike another vehicle during the course of the accident (i.e., single-vehicle collisions). The FARS data show that 94 percent of the fatalities were also in single-vehicle accidents. Because the vast majority of side-impact, fixed-object accidents involved only one vehicle, removal of multiple-vehicle collisions did not adversely affect the data.

Table 8. Number of vehicles in side-impact fixed-object accidents.

Number of Vehicles	1980-85 FARS Frequency	1980-85 FARS Percent	1982-85 NASS Frequency	1982-85 NASS Percent †
1	2096	94	212,753	94 ± 3
2	135	6	13129	6 ± 3
3	9	0	473	0-2
4	1	0	98	0-2
5	1	0	17	0-2
Total	2242	100	226,470	100

† 68th percentile confidence interval.

Table 9 shows that roughly 80 percent of the occupants in single-vehicle, side-impact, fixed-object accidents were in passenger cars. This is true for both the FARS and the NASS data bases. Utility vehicles,vans and light trucks account for 12 percent of the occupant fatalities. Because passenger car safety has the most potential for improvement, removing all other vehicle types made this study more meaningful.

Table 10 shows how the study sample was formed. After removing non-side collisions, multiple-vehicle accidents, and non-passenger vehicle collisions from the study sample, the remaining number of side-impact, fixed-object occupant exposures (NASS data) was 168,359 and the number of fatalities (FARS data) was 1,647. Unless otherwise noted, all remaining data will consist of single-passenger-vehicle, side-impact, fixed-object collisions. These accidents will be referred to as side-impact, fixed-object collisions.

THE FIXED OBJECTS

The first step in improving safety in fixed-object collisions is to determine which objects cause the most severe injuries and deaths. Table 11 lists the types of objects that are hit most frequently. The objects were split into three general categories: narrow, broad, and other. The variables listed conform to the FARS data definitions. Some of the NASS variables were combined to conform to the FARS data. For example, the two NASS variables for trees – greater than 152-mm diameter and less than 152-mm diameter – were combined for consistency with the FARS data which has only the single variable, "trees."

An inspection of table 11 reveals that occupants were most likely to strike narrow objects. There were three times as many collisions with narrow objects as broad objects. Occupants who were exposed to fixed-object collisions hit narrow objects 59 percent of the

Table 9. Type of vehicle in single-vehicle, side-impact, fixed-object collisions.

Vehicle Type	1980-85 FARS Frequency	Percent	1982-85 NASS Frequency	Percent †
Passenger Car	1,647	79	168,359	79 ± 5
Vans, Light Trucks, and Utility Vehicles	262	12	26,481	12 ± 4
Motorcycle	151	7	4,686	2 ± 2
Truck	21	1	11,900	6 ± 3
Bus	5	0	1,204	1 ± 2
Other	10	1	123	0-2
Total	2,096	100	212,753	100

† 68th percentile confidence interval.

Table 10. Creating the study sample.

Type of Collision	1980-85 FARS	1982-85 NASS
Fixed Object	8,798	914,180
Side Impact, Fixed Object	−2,241	−226,470
Single Vehicle, Side, Fixed	−2,096	−212,753
Passenger Vehicle, Single, Side, Fixed	1,647	168,359

Table 11. Fixed objects struck in single-passenger vehicle side-impact, fixed-object accidents.

Object Struck	1980-85 FARS Frequency	1980-85 FARS Percent	1982-85 NASS Frequency [1]	1982-85 NASS Percent [2]
NARROW				
Tree	785	48	41,517	25 ± 6
Utility Pole	434	26	35,996	22 ± 6
Light Support	45	3	5,519	3 ± 2
Other Post/Pole	39	2	7,405	4 ± 3
Sign Support	11	1	6,958	4 ± 3
Mail Box	–	–	2,189	1 ± 1
Delineator Post	–	–	413	0 ± 1
SUBTOTAL	1314	80	99,997	59 ± 7
BROAD				
Guardrail	70	4	15,996	9 ± 5
Bridge Pier/Abutment	44	3	1,796	1 ± 1
Bridge Parapet	24	1	414	0 ± 1
Wall	18	1	2,288	1 ± 1
Fence	15	1	4,572	3 ± 2
Bridge Rail	11	1	1,921	1 ± 1
Concrete Barrier	4	0	1,287	1 ± 1
Impact Attenuator	1	0	239	0 ± 1
Other Long. Barrier	2	0	1,851	1 ± 1
SUBTOTAL	189	11	30,364	18 ± 6
OTHER				
Culvert	30	2	970	1 ± 1
Other Fixed Object	30	2	6,784	4 ± 3
Building	25	2	1,063	1 ± 1
Embankment, Unknown	21	1	–	–
Embankment, Earth	13	1	6,608	4 ± 3
Ditch	15	1	10,042	6 ± 4
Embankment, Rock	6	0	1,480	1 ± 1
Curb	2	0	11,051	7 ± 4
Fire Hydrant	1	0	–	–
Shrubbery	1	0	–	–
SUBTOTAL	144	9	37,998	24 ± 6
TOTALS	1,647	100	168,359	100

[1] A dashed line indicates the object was not in the data set.
[2] 68th percentile confidence interval.

time, broad objects 18 percent, and other objects 23 percent. Trees and utility poles were the objects most often struck, accounting for nearly 50 percent of the collisions. Guardrails were hit about 10 percent of the time. No other object accounted for more than 10 percent of the study sample.

Not only were occupants exposed to more narrow-object collisions, they were fatally injured in narrow-object collisions more often than in collisions with broad or other objects. Eighty percent of the fatalities involved impacts with narrow objects, although only 59 percent of the occupant involvements were with narrow objects. In the cases of trees and poles there are enough accident cases to show that the differences between the NASS and FARS data is statistically significant. For narrow objects as a class, the difference between the FARS and NASS data is statistically significant. Although between 52 and 66 percent of all side-impact collisions involve narrow objects, 80 percent of the fatalities involve narrow objects. Narrow objects, then, seem to be especially hazardous objects to strike in side-impact collisions.

Occupants were killed in 1 out of 75 (0.013) of the narrow-object collisions and 1 out of 160 (0.006) of the broad-object collisions. Narrow-object collisions appear to be twice as likely to result in fatalities as broad-object collisions. Even these results may understate the harmfulness of narrow-object side impacts since the two most harmful broad objects – guardrails and bridge piers/abutments – would be considered narrow object collisions if they were struck on the end.

Trees were the most numerous harmful objects. They were the object struck in between 19 and 31 percent of the occupant involvements, but were responsible for 48 percent of the fatalities. Trees are especially dangerous because they are narrow, rigid, and tall (A tall object in this context simply means one which is capable of striking an occupant's head in a nonrollover side-impact collision). When the point of impact with the fixed object is adjacent to a vehicle occupant, these three characteristics combine to result in a dangerous accident scenario.

ROLLOVER INVOLVEMENT

As noted earlier, accidents in which the MOST-HARMFUL-EVENT variable was coded as a noncollision overturn or ground collision were removed. The accident study did, however, include rollovers when the MOST-HARMFUL-EVENT was a fixed object. Table 12 shows the number of side-impact, fixed-object collisions which involved a rollover. Of the estimated 13,799 occupants involved in rollovers, 1.4 percent, or 197, were killed. When the collision did not include a rollover, about 1 percent, or 1,450 of the 154,560 occupants involved were fatally injured. Even though rollovers are more likely to result in a fatality, they are involved in only 12 percent of the side-impact, fixed-object collisions and thus are not considered to be a significant contributor to injury in the fixed-object accident scenario.

Table 12. Rollover involvement.

Rollover	1980-85 FARS		1982-85 NASS	
Variable	Frequency	Percent	Frequency	Percent †
Rollover	197	12	13,799	8 ± 4
No Rollover	1,450	88	154,560	92 ± 4
Total	1,647	100	168,359	100

† 68th percentile confidence interval.

SEATING POSITION

Figure 5 shows the percentage of occupants in each seating position. The NASS figures represent the percent of all occupants in each seating position when the impact is from the side shown. The FARS numbers represent the percent of all occupants killed in that particular seating position when the impact is from the side shown. These figures help illustrate the seating position where the occupant is most at risk. Figure 5 shows that approximately half of the collisions (NASS) occurred on the driver side and half on the passenger side. The percentage of occupants on both the driver side and passenger side is nearly the same for both directions of impact. The top two vehicles in figure 5 show that 6 percent more of the fatal collisions are due to impacts on the driver's side than on the passenger side. When the impact was on the driver's side, 78 percent of the fatalities were drivers. This figure seems to indicate that although side impacts occur with equal frequency on both sides of the vehicle, the struck-side occupant has the greater chance of being injured.

Table 13 is a summary of collisions from both sides. It combines the collisions into near-side and far-side impacts. By looking at the NASS data, it can be seen that approximately half of the occupants were located on the near side and half on the far side of the impact. In other words, the side where the impact occurs is apparently random. In fatal accidents, however, 59 percent of the fatalities occurred on the same side of the vehicle as the impact. The near-side collisions warrant top priority in terms of safety improvements, although the far-side collisions should not be ignored as they account for 35 percent of the fatalities.

VEHICLE TYPE

One of the characteristics of vehicles that could affect passenger safety in side-impact collisions with fixed object is the vehicle size. Table 14 lists the mass of vehicles in the

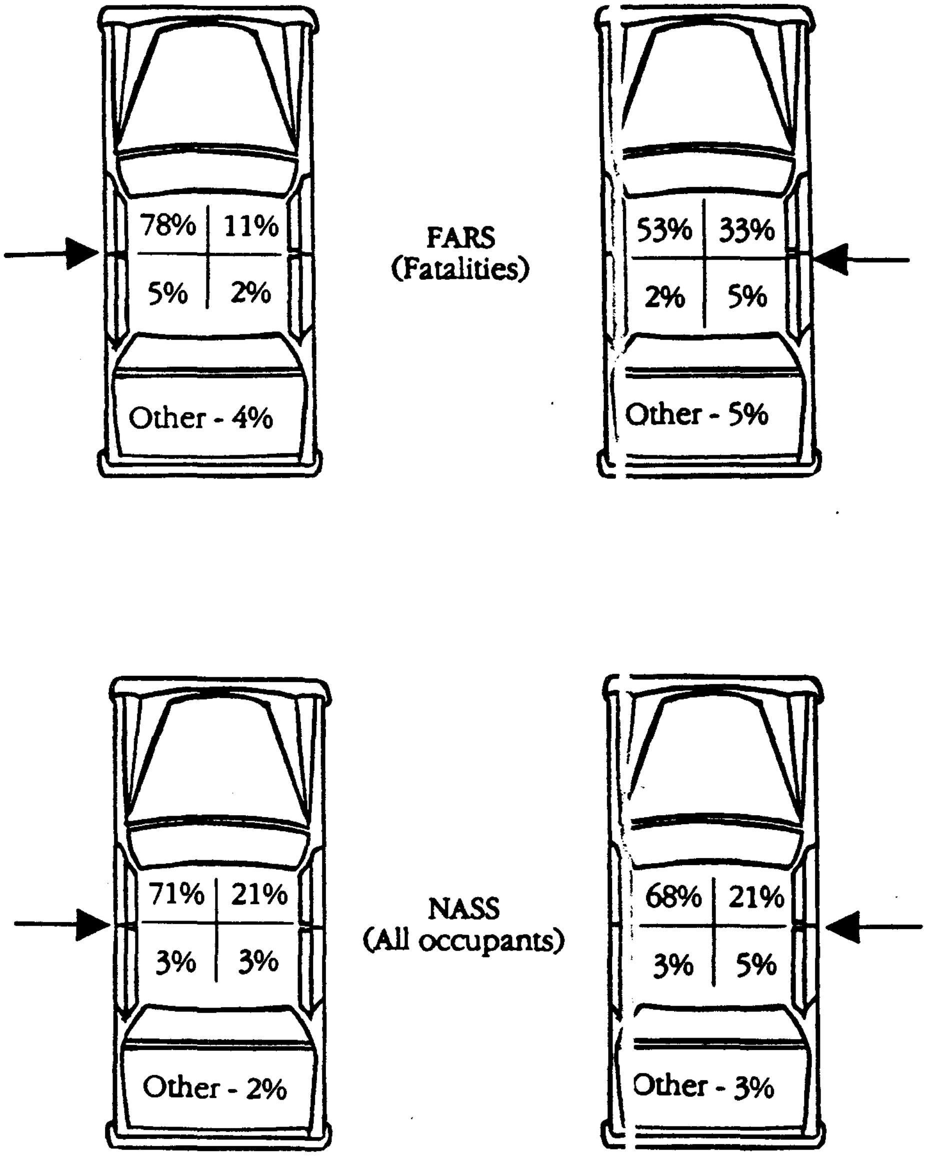


Figure 5. Percent of occupants in each seating position.

Table 13. Summary of near and far side occupants.

Location of Impact	1980-85 FARS Frequency	Percent	1982-85 NASS Frequency	Percent †
Near Side	974	59	81,348	48 ± 7
Far Side	579	35	79,395	47 ± 7
Other	94	6	7,616	5 ± 3
Total	1,647	100	168,359	100

† 68th percentile confidence interval.

FARS and NASS data. The weight group that contains the most occupants exposed to side-impact, fixed-object collisions is the 1,450 to 1,720 kg group. Nearly 30 percent of the occupants were in vehicles in this weight range. This is also the weight group with the most fatalities (29 percent) as seen in the FARS data. These figures do not necessarily indicate that this weight range is the most dangerous. If the percentage of fatalities in a weight range is the same as the percentage of registered vehicles in that weight range, then that particular vehicle size is not more at risk than any other.

In order to determine whether occupants in lighter vehicles were more at risk than occupants in heavy vehicles, the FARS and NASS data were compared to the Polk registration data. A comparison of the NASS data with registration data shows whether the percentage of occupants involved in collisions in a certain weight of vehicle is greater than the percentage of registered vehicles of that weight. A comparison of the FARS data with registration data shows whether the percentage of fatal collisions in a particular weight range is greater than the percentage of registered vehicles in that weight range. If the NASS data is assumed to be a reasonable representation of the occupants involved in each weight range, then a similar distribution of NASS and FARS would indicate that, given an occupant is in a fixed-object, side-impact collision, the person is equally likely to be fatally injured in any weight of vehicle. The issue of other variables, like age, masking the weight effect was not explicitly addressed. Age-masking can occur when a large number of elderly occupants are in the data set. Older occupants should more likely be injured when they are involved in an accident, and they generally drive large cars.[11] These two characteristics combined might increase the fatality rate in heavy vehicles. In this study, 91 percent of the occupants involved in fixed-object, side-impact collisions were under the age of 44 (see table 26) and 84 percent were under 34 years of age, so age-masking does not appear to be a serious problem.

Because the mean vehicle weight has been dropping each year, it was important to compare FAR, NASS, and registration data for a single year to eliminate any time variation. The FARS and NASS data from 1983 were compared to the 1983 registration data. Figure 6 shows the cumulative distribution functions (CDF) of the weights of

Table 14. Occupant involvement by passenger vehicle weight.

Vehicle	**1980-85 FARS**		**1982-85 NASS**	
Weight(kg)	Frequency	Percent	Frequency	Percent †
Under720	64	1	3,106	2 ± 2
720	86	1	0	0 ± 1
810	339	4	2,408	1 ± 1
910	525	6	10,342	6 ± 4
1000	393	4	16,213	10 ± 4
1090	735	8	9,153	5 ± 3
1180	854	10	13,190	8 ± 4
1270	708	8	10,958	6 ± 4
1360	784	9	11,474	7 ± 4
1450	1,074	12	13,277	8 ± 4
1540	815	9	17,141	10 ± 4
1630	724	8	17,707	11 ± 5
1720	501	6	11,515	7 ± 4
1810	494	6	10,893	7 ± 4
1900	396	5	7,307	4 ± 3
1990	139	2	5,651	3 ± 2
2080	114	1	1,991	1 ± 1
2170	41	0	4,878	3 ± 2
2260	56	0	611	1 ± 1
2360	4	0	214	0 ± 1
Over 2360	9	0	327	0 ± 1
Total	8,855	100	168,359	100
Missing	1,028		0	

† 68th percentile confidence interval.

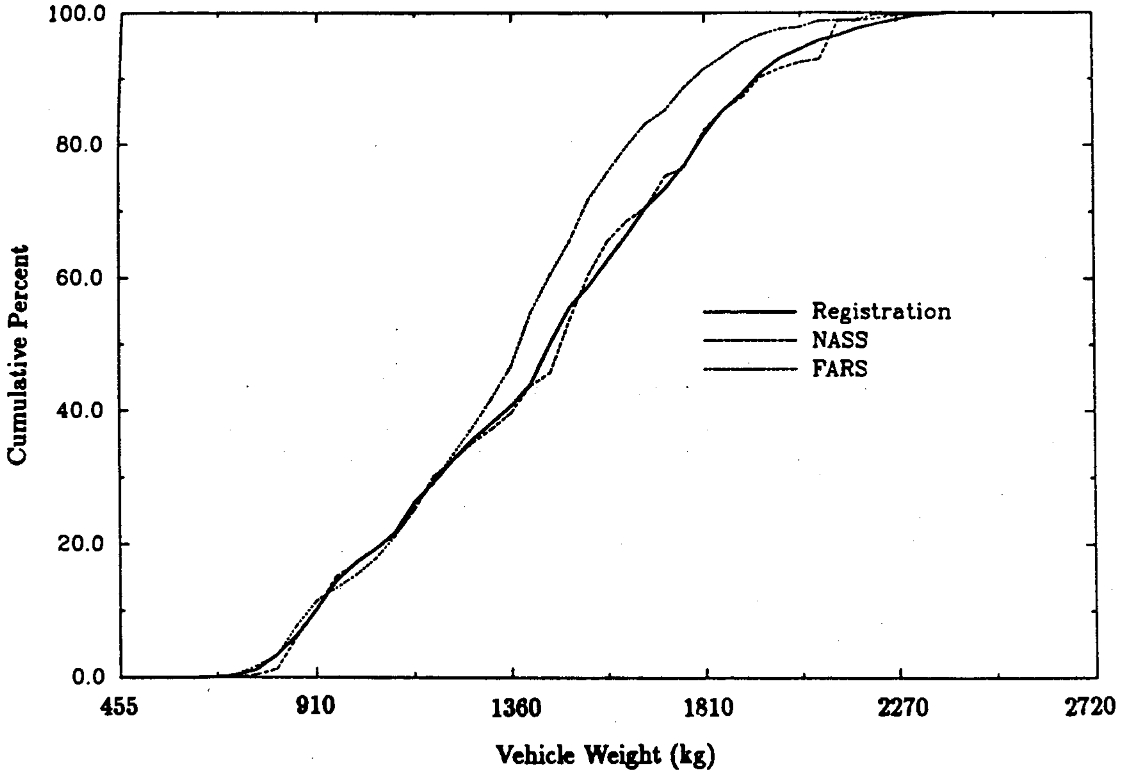


Figure 6. Cumulative distribution function for 1983 FARS, NASS, and registration data.

vehicles involved in all severities of side-impact collisions (NASS) and in fatal side-impact collisions (FARS) along with the CDF of the weights of registered vehicles. The FARS curve appears to vary from the registration curve in the 1,270- to 1,450-kg range. The maximum difference between the NASS and registration data sets was 4 percent and 13 percent between the FARS and the registration data sets. The Kolmogorov-Smirnov and the Chi-squared goodness-of-fit tests were met at the 80 percent confidence level or greater for both the NASS-registration comparison and the FARS-registration comparison. This difference between the FARS and registration data may be further reduced by considering the differences in reporting vehicle weight in these two data sets. Partyka contends that the vehicle weights reported in FARS are generally 45 to 140 kg less than the Polk registration generated weights.[12] She also notes that accounting for this difference significantly reduces the fatality rate in lighter cars. A correction of the FARS weights in figure 6 would essentially move the CDF for the FARS data to the right 45 to 140 kg, producing a closer fit of this curve with the registration data CDF. Vehicle occupants appear to be at equal risk in heavy as well as light vehicles. For the case of side impacts with fixed objects, bigger cars are not necessarily safer than smaller cars.

Table 15. Occupant involvement by roadway type.

Roadway Type	1980-85 FARS Frequency	1980-85 FARS Percent	1982-85 NASS Frequency	1982-85 NASS Percent †
Interstate	84	6	13,495	8 ± 4
U.S. Highway	152	11	18,279	11 ± 5
State Highway	428	30	41,033	24 ± 7
County Road	370	26	48,548	29 ± 7
Local Road	333	24	44,656	27 ± 7
Other	50	3	2,292	1 ± 1
Total	1,417	100	168,303	100
Missing	230		56	

† 68th percentile confidence interval.

ROADWAY TYPE

Determining the type of roadway where side-impact, fixed-object accidents occur is important for improving roadway design standards and directing public funds. Table 15 shows that the majority of accidents and fatalities take place on State, county, and local roadways; over 50 percent on county and local roads alone. A small percentage of fixed-object, side-impact accidents and fatalities occur on Interstates. According to the FARS data, guardrails are responsible for most of the fixed object fatalities on Interstates. Trees and utility poles cause the most fatal injuries on all other roadway types.

Interstates carry over 21 percent of vehicle travel, yet experience only 8 percent of the accidents and 6 percent of the fatalities.[13] The underrepresentation of Interstates in side-impact, fixed-object collisions and fatalities may be due to higher design standards and wider clear zones than local and county roads. Interstates are better maintained and have more stringent requirements on curves and sight distances. This underrepresentation of collisions and fatalities on Interstates seems to suggest that these standards do reduce the number of side-impact collisions and fatalities.

Even though most of the collisions and fatalities occur on State, county, and local roadways, most of these roadways receive some type of Federal assistance. Table 16 shows that two-thirds of the occupant involvements in both the FARS and NASS data occur on roadways receiving some type of Federal aid. The Federal Government, then, has some ability to implement roadway safety measures by establishing policies and procedures that decrease side impacts with fixed objects.

Table 16. Occupant involvement by Federal-aid classification.

Federal Aid Classification	**1980-85 FARS** Frequency	Percent	**1982-85 NASS** Frequency	Percent †
Federal Aid System				
Interstate	65	6	13,495	8 ± 4
Other primary	256	25	30,983	18 ± 6
Secondary	205	19	27,209	16 ± 5
Urban Arterial	158	15	24,537	15 ± 5
Urban Collector	61	6	16,656	10 ± 4
Total Fed. Aid	745	69	112,880	67 ± 7
Nonfederal Aid System				
Urban Arterial	20	2	688	0 ± 1
Urban Collector	83	8	11,578	7 ± 4
Local Collector	240	22	43,195	26 ± 7
Total Nonfed. Aid	343	32	55,461	33 ± 7
Total	1,642	100	168,341	100
Missing	5		18	

† 68th percentile confidence interval.

ROADWAY ALIGNMENT

One of the reasons more accidents occurred on county and local roads may be that they have more or sharper curves than the Interstates or U.S. highways. Table 17 shows the percentage of accidents that occurred on straight and on curved roads. The NASS data shows that the majority (58 percent) of occupants exposed to fixed-object collisions were on straight roads. Close to half of the fatalities, however, occurred on curved roads. In order to determine whether curved roads are more dangerous, it is necessary to compare the percentage of vehicle miles traveled on curved roads to those on straight roads. Out of 6,246,056 km of road in the U.S., 74 percent are straight sections and 26 percent are curved.[13] Table 18 shows involvement and fatality rates per 100,000 km of each type of alignment. Accidents on curved roadway sections occurred more frequently and were more injurious than on straight sections. Over twice as many occupants were involved in accidents per kilometer of curved road as per kilometer of straight section and the accidents on curved roads resulted in nearly three times as many fatalities per kilometer as per kilometer of straight section.

Table 17. Occupant involvement by roadway alignment.

Roadway Alignment	**1980-85 FARS** Frequency	Percent	**1982-85 NASS** Frequency	Percent †
Straight	845	51	90,975	58 ± 8
Curve	799	49	65,470	42 ± 8
Other	3	–	–	–
TOTALS	1,647	100	156,445	100
Missing			11,914	

† 68th percentile confidence interval.

Table 18. Occupant involvement rate per 100,000 km of roadway.

Roadway Alignment	**Total Kilometers**	**1980-85 FARS**	**1982-85 NASS**
Straight	4,644,179	18.2	1,959
Curve	1,597,998	50.0	4,097
TOTALS	6,242,177	26.4	2,506

Table 19. Occupant involvement by surface condition.

Surface Condition	1980-85 FARS Frequency	1980-85 FARS Percent	1982-85 NASS Frequency	1982-85 NASS Percent †
Dry	1,238	75	86,987	53 ± 8
Wet	305	19	50,096	30 ± 7
Snow/Slush	40	2	8,428	5 ± 3
Ice	51	3	19,308	12 ± 5
Other	14	1	908	0 ± 1
Totals	1647	100	165,727	100
Missing			2,632	

† 68th percentile confidence interval.

Table 20. Average daily occupant involvement by weather condition.

Weather Condition	Number of Days	1980-85 FARS	1982-85 NASS
Dry	257	4.8	339
Wet	108	3.7	721

SURFACE CONDITIONS

Because non-sideswipe side-impacts with fixed objects require the vehicle to be yawing or sliding sideways, it would seem that weather and other adverse road conditions should contribute to side-impact collisions. This is not bourne out by the data however. As seen in table 19, 53 percent of the occupant exposures and 75 percent of the fatalities occurred on dry roads. This data implies that side-impact, fixed-object collisions are far more dangerous on dry roads than on slick roads. When normalized by the number of dry days and wet days in an average year, the collisions on dry surfaces seem to be even worse. Table 20 shows the average number of dry days and days with some precipitation for 100 cities throughout the United States.[14] The NASS data shows the number of occupants involved and the FARS data show the number of fatalities in side-impact, fixed-object collisions. The chance of being involved in a side-impact accident on a wet day is twice as high as on a dry day, but the chance of being fatally injured in a side-impact accident is higher on dry days. Slower speeds on icy, wet, or snowy roads may be one reason for fewer fatalities on these surface conditions.

Table 21. Occupant fatalities by extent of deformation and impact locations.

Extent of Deformation	**1980-85 FARS Other**	**Near Side**	**Far Side**
None	1	3	6
Other	5	29	20
Functional	25	281	153
Disabling	553	5,516	3,281

DEFORMATION

The information on deformation in table 21 is taken from the FARS data only. Table 21 shows that the extent of deformation and fatalities are apparently related. The next chapter will further explore the relationship between extent of deformation and occupant injuries using the NASS data.

4 INVESTIGATION OF THE NASS DATA

The previous chapter dealt with those characteristics of single- passenger-vehicle, side-impact, fixed-object collisions which were represented in both the FARS and NASS data bases. A comparison was made of the number of people exposed to this type of accident with the number of people fatally injured. This chapter takes a closer look at the levels of injury experienced by occupants along with other data that were not available in the FARS data base. Details such as body region injured, velocity and direction of vehicle, and magnitude of intrusion point to a clearer understanding of the impact conditions in side-impact collisions. Again in this chapter, the term "side-impact collision" will refer to a single passenger-vehicle, side-impact, fixed-object collision.

Table 22 shows the police-reported injuries for side-impact collisions that are recorded in the NASS data. Of the 163,711 occupants involved in side-impact collisions, 43,371 (26 percent) were known to be injured and 1,555 (1 percent) were killed. These results agree with the FARS data discussed in chapter 3: Approximately 1 of every 100 people involved in side-impact collisions in the NASS data were fatally injured. Recall that the values in NASS data are projections of the number of occupants involved and are derived from statistically bias-corrected samples. The FARS data shows that an average of 1,647 occupants per year were fatally injured in the years 1980 through 1985. The NASS data provides a reasonable estimate of 1,555 fatalities per year based on the years 1982 through 1985.

GUARDRAILS

In chapter 3, it was shown that guardrails were involved in 9 percent of all occupant exposures to fixed-object, side-impact accidents and in 4 percent of the fatal ones. The NASS data on guardrail collisions, which is broken into five categories, appears to show that particular characteristics of guardrails are responsible for most of the injuries. Two of the NASS guardrail categories pertain to the midsection of a guardrail and the other three involve guardrail ends and transitions. Guardrail ends are defined in the NASS coding manual in English units as sections within 25 ft (8 m) of the upstream end of the guardrail.[15] The upstream end is defined as the end upstream from the direction of vehicle travel, not according to the side of the road where the guardrail is located. Figure 7 shows the leading edges for a vehicle traveling in the direction shown on a nonmedian roadway. A collision with either of the leading edges would be considered an "end collision." Hitting the trailing edge of either guardrail would not.

Table 23 shows the estimated number of occupants involved in each type of guardrail collision and the percentages in the police-reported-injury categories for no, possible, or minor injury. It was assumed in the previous chapter that guardrails were broad objects. This would be appropriate if all were midsection collisions. Guardrail ends and transitions

Table 22. Estimate of occupant injury in side-impact collisions.

Type of Injury	Frequency	Percent †
No Injury(0)	102,071	62 ± 7
Possible Injury(C)	18,270	11 ± 5
NonIncapacitating Injury(B)	25,919	16 ± 5
Incapacitating Injury(A)	14,585	9 ± 4
Killed(K)	1,555	1 ± 1
Unknown	1311	1 ± 1
Total	163,711	100.0
Missing	4,648	

† 68th percentile confidence interval.

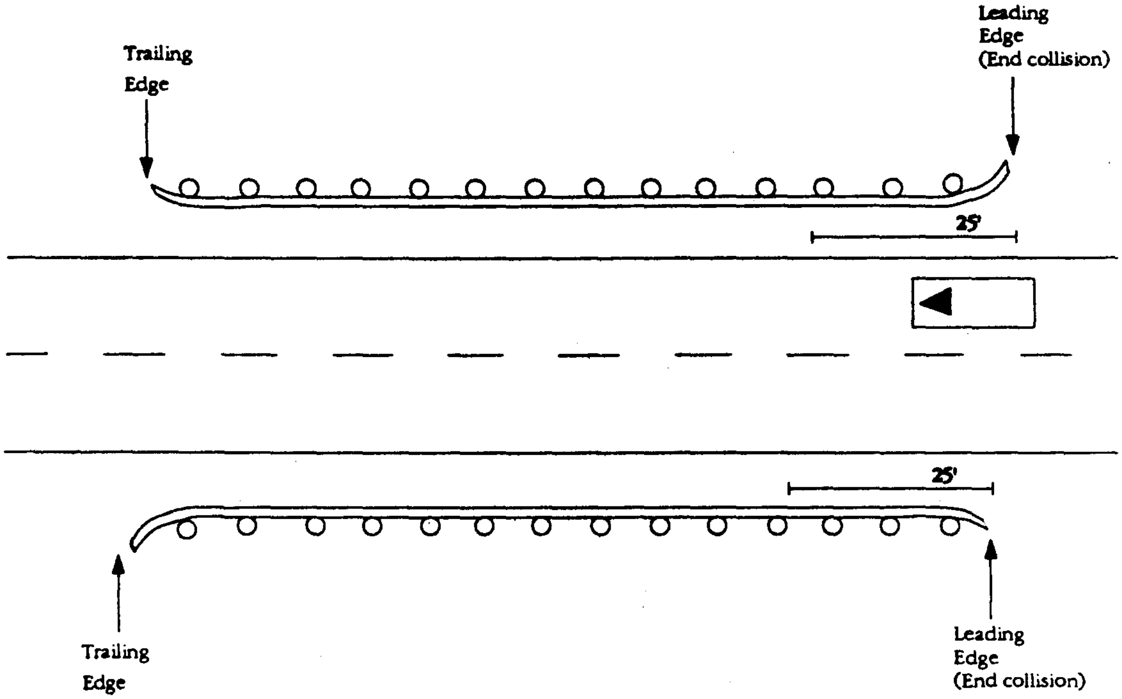


Figure 7. Definition of guardrail end in NASS data.

Table 23. Estimate of occupant involvement in guardrail collisions.

	Police Reported Injury					
Guardrail Type	No,Possible, or Minor Injury(0+B+C)		Incapacitating Injury(A) ‡	Killed(K) ‡	Total	
	Freq.	Percent †	Freq.	Freq.	Freq.	Percent †
Non-Median	11,402	75 ± 21	374	0	11,776	74 ± 21
Median	2,185	14 ± 17	60	0	2,245	14 ± 17
Bridge Transition	352	2 ± 7	0	22	374	2 ± 7
End(Non-Median)	1,309	9 ± 14	61	18	1,388	9 ± 14
End(Median)	14	0 ± 6	127	14	155	1 ± 6
Totals	15,262	100	622	54	15,938	100
Missing					58	

† 68th percentile confidence interval.

‡ Sample size too small to calculate confidence intervals.

may more accurately fit into the narrow object category. The reason bridge transitions may be more accurately categorized as narrow objects has to do with the difference in stiffness of guardrails and bridgerails. Guardrails are flexible, whereas bridge rails are rigid. When a vehicle hits the guardrail first, the rail can deflect as much as 1 m. On the other hand most bridge rails are rigid. An ineffective transition allows the bridge rail to act as a narrow object because the guardrail deflects and exposes the side of the vehicle to the blunt end of the bridgerail. Bridge rail ends may cause many of the fatalities in the transition collisions. All the fatal guardrail collisions in the NASS data sample involved ends or transitions (narrow objects) rather than midsections (broad objects); therefore, those fatal collisions in table 11 which involved guardrails could have been included as narrow objects rather than as broad ones.

Table 23 shows that there were over 14,000 collisions with midsections and fewer than 2,000 with end sections and transitions. All the fatalities in this sample were due to impacts with end sections and transitions. Clearly the narrow portion of the guardrail is more dangerous than the midsection with more than 1 fatality for every 50 side-impact collisions with end sections, and more than 1 fatality for every 20 impacts with bridge transitions. Not a single fatality, however, was included in the estimated 14,021 side impacts with mid-sections of guardrails. While there are too few severe injury cases to make statistically meaningful conclusions, table 23 does suggest that guardrail ends and transitions are very dangerous objects in side impacts.

The example in figures 8 and 9, taken from a NASS-Longitudinal Barrier Special Studies (LBSS) case, demonstrates why blunt guardrail ends are especially dangerous. After traveling around a curve at high speed, the driver lost control of the vehicle. The vehicle crossed over to the wrong side of the road and then onto the left shoulder. As the driver attempted to bring the vehicle back to the roadway, it struck the blunt end of the guardrail near the driver's side fire wall. A blunt end was used since it was the "upstream" end for the adjacent travel lane. The photographs in the figure show where the guardrail entered and exited the vehicle. Fortunately, the driver survived uninjured.

Designing safe and effective guardrail terminals for frontal impacts has been a persistent problem in the field of roadside safety for years. Overall, however, guardrails appear to have been effective in preventing injury. Most occupants represented in table 23 received no injuries. Guardrails as a whole caused fewer fatalities than narrow objects did. Collisions with guardrail ends, however, resulted in fatalities more often than collisions with other types of narrow objects. In this sample, 1 in 50 occupants were killed in side collisions with guardrail ends, while only 1 in 75 were killed in side-impact collisions with all types of narrow objects.

LOCATION OF IMPACT

Collisions at certain locations on the side of a vehicle seem to be more dangerous than at other locations. Figure 10 shows the locations on the side of a vehicle used in the NASS data to indicate where the most harmful impact occurred. The passenger compartment, labeled "P", extends from the base of the windshield to the rear of the rearmost seat. The "F" and "B" areas extend from the passenger compartment to the front and to the rear of the vehicle, respectively. A code of "Y" or "Z" indicates that the damage covered a combination of two areas as shown in the figure. The "D" code means that the damage was distributed over the entire side of the vehicle.

Because the occupants are located in the passenger compartment, it is reasonable to expect that collisions to this area would result in the most and the worst injuries. Table 24 shows that collisions at the passenger compartment (P) did seem to cause more incapacitating(A+K) injuries than collisions at other areas. Twenty percent of the passenger compartment collisions and 18 percent of those damaging the "Y" section, which includes the passenger compartment, resulted in incapacitating injuries. As shown in table 24, occupants involved in collisions located in these two areas are twice as likely to sustain incapacitating injuries as those in all other areas.

Table 25 shows the injury distribution in collisions where the most severe damage was located solely within the passenger compartment of the vehicle. When compared to table 22, it appears that passenger compartment collisions are more dangerous than side impacts in general. In table 22, 62 percent of the occupants were not injured. In passenger compartment collisions, shown in table 25, only 46 percent were not injured. An occupant has a 1 in 100 chance of being fatally injured in side-impact collisions in general, but has almost 1 chance in 40 of being killed when the damage is located at the passenger

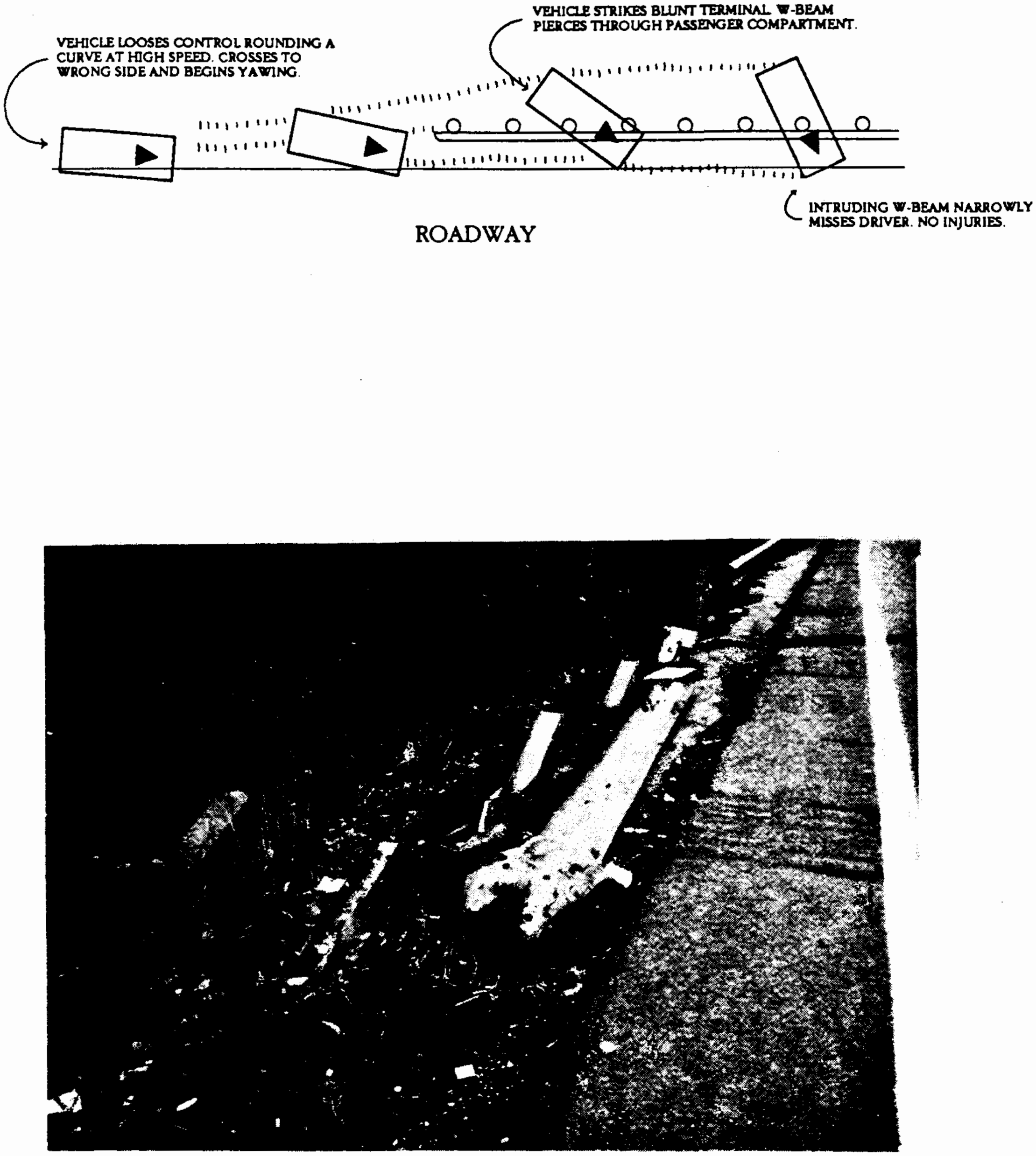


Figure 8. Vehicle path and guardrail end in collision example. (NASS-LBSS Case 83-08-512T)

Figure 9. Interior view of guardrail end collision (NASS-LBSS Case 83-08-512T).

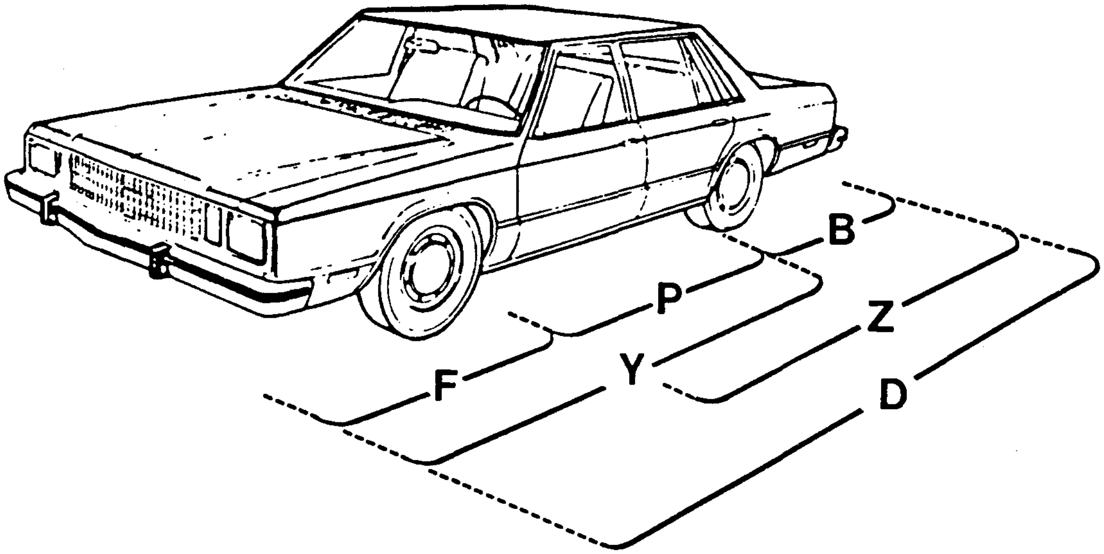


Figure 10. Labels used in location of impact. [4]

Table 24. Estimated occupant involvements by location of impact.

Location of Impact	Nonincap. (0+B+C)		Incap. A+K		Unknown	Total	
	Freq.	Percent †	Freq.	Percent †	Freq.	Freq.	Percent †
Unknown	43,885	93 ± 7	3,269	7 ± 7	112	47,266	29 ± 7
F	28,189	94 ± 8	1,683	6 ± 8	200	30,072	18 ± 6
D	20,201	89 ± 13	1,949	9 ± 11	407	22,557	14 ± 5
P	15,837	79 ± 17	4,003	20 ± 17	152	19,992	12 ± 5
Z	14,972	88 ± 15	1,744	10 ± 14	310	17,026	10 ± 5
Y	12,039	82 ± 19	2,576	18 ± 19	0	14,615	9 ± 4
B	11,138	91 ± 16	915	8 ± 16	131	12,184	8 ± 4
Total	146,261	89 ± 5	16,139	10 ± 5	1,312	163,712	100
Missing						4,647	

† 68th percentile confidence interval.

Table 25. Estimate of occupant involvement by injury in passenger compartment collisions.

Type of Injury	Frequency	Percent †
No Injury (0)	9,271	46 ± 21
Possible Injury (C)	2,133	11 ± 13
Non-Incapacitating Injury (B)	4,433	22 ± 17
Incapacitating Injury (A)	3,521	18 ± 16
Killed (K)	482	2 ± 6
Unknown	152	1 ± 6
Total	19,992	100.0

† 68th percentile confidence interval.

compartment. It appears that a passenger compartment collision is more than twice as likely to result in a fatality as a side-impact collision in general.

The importance of the location of impact was illustrated by the blunt-end guardrail accident in figure 8. If the rail had intruded the vehicle just a few inches closer to the passenger, there would have been a serious injury or death. The location of impact is also important in collisions with tall narrow objects. In order for the occupant to directly strike a tall, narrow, rigid object, the impact must be located at the passenger compartment. Table 24 showed that most of the incapacitating injuries do seem to occur in this area. Occupants are at risk of directly contacting exterior objects in side-impact, fixed-object collisions when the collision occurs at the passenger compartment.

AGE AND TIME

Two other notable characteristics of side-impact, fixed-object collisions are the age of the vehicle occupant and the time of day of the accident. As shown in table 26, 91 percent of the occupants involved in this type of collision were under the age of 35. The age group most frequently involved was 16- to 19-year-olds. This age group, which includes only 4 years, accounts for 30 percent of side-impact collisions. Inexperience and high-speed driving are both characteristics of this age group. It is not surprising that the age group that is most often involved in these collisions is the one that travels at higher speeds and has the least experience in avoiding collisions.

From table 27 it is apparent that most of the side-impact collisions with fixed objects occurred at night. Over 50 percent of the occupants were involved in accidents that happened between 8 p.m. and 4 a.m.

Table 26. Estimate of occupant involvement by age of occupants.

Age	Freq.	Percent †	Cum. Percent
0-15	10,068	6 ± 15	6
16-19	48,113	30 ± 13	36
20-24	44,102	27 ± 13	63
25-34	33,333	21 ± 14	84
35-44	12,083	7 ± 14	91
45-54	5,107	3 ± 14	94
55-64	3,765	3 ± 14	97
Over 64	5,454	3 ±	100

† 68th percentile confidence interval.

Table 27. Estimate of occupant involvement by time of accident.

Time	Frequency	Percent †	Cum. Percent
8pm-12am	38,422	23 ± 13	23
12-4 am	45,913	28 ± 13	51
4-8 am	16,884	10 ± 14	61
8am-12pm	14,799	9 ± 14	70
12-4 pm	19,931	13 ± 14	83
4-8 pm	28,188	17 ± 13	100

† 68th percentile confidence interval.

BODY REGION

The NASS data contains information about which region of an occupant's body was most seriously injured. The accident cases in the previous sections included multiple-collision accidents in which the most harmful event was a side impact with a fixed object. This section attempts to assign an injury in a specific body region to a specific type of impact. To ensure that the injury to a body region is correctly attributed to a side impact, only single-event collisions were considered in this section. In other words, if a vehicle hit a bridge rail, spun around and collided with a tree on the side, the worst injury to a body region may have been due to either of the collisions. By limiting the study to single-collision accidents, the injury may be correctly attributed to the side-impact collision with a fixed object. Because of this restriction, the number of occupants in this section will be significantly fewer than in the previous sections.

Table 28 lists the body region with the highest AIS for each occupant that was injured in a single-event, side-impact collision with a fixed object. The first two columns of this table are for all injury severities. The face, head-skull, and neck-cervical spine were the three areas most frequently injured.

The second group of columns in table 28 shows the body regions most frequently injured on occupants whose highest AIS was greater than three. The sample size was too small to calculate confidence intervals, so the percentages have been eliminated. There is a wide margin for error in the following table but the information is presented because it provides vital clues about injury mechanisms in side impacts with fixed objects. Recall from chapter 2, an injury with an AIS greater than three is considered life-threatening. Presumably because of the vital organs in the head and chest, most of the severe injuries are in these areas. The head-skull area accounts for 291 of the 554 cases with $AIS > 3$ injuries. The chest is the second most often severely injured area with 169 of the 554 injuries with AIS's greater than three.

It is not surprising that the areas above the shoulders are the most frequently injured body regions and that the head is the region most seriously injured. Because passenger vehicles are not designed to travel sideways, when they do, they begin to roll. The top of the vehicle is usually the first to strike an object in side impacts especially when the object is tall. This may account for the dominance of head, face, and skull injuries. Additionally, seat belts provide little or no lateral restraint for the upper body in side impacts. A side impact would cause the areas above the shoulders to collide with the interior of the vehicle or with exterior objects through the window. The head is offered little protection from exterior objects that strike the vehicle at the passenger compartment.

Table 29 is a list of some of the most frequently or most severely injured body regions and the type of object that the accident investigator judged caused the injury. Guardrail ends and transitions were considered narrow objects in this table. In three of the four body

Table 28. Estimated occupants by body region injured.

Body Region	**All Injuries**		**AIS Over 3** [‡]
	Freq.	Percent [†]	Freq.
Head-Skull	5,263	18 ± 14	291
Chest	1,949	7 ± 9	169
Whole Body	295	1 ± 5	50
Abdomen	429	1 ± 5	44
Face	6,472	22 ± 15	-
Neck-Cerv.Spine	3,727	13 ± 12	-
Injured, Unknown	1,746	6 ± 9	-
Knee	1,397	5 ± 8	-
Wrist	1,268	4 ± 7	-
Shoulder	1,266	4 ± 7	-
Back-Thorac.Spine	1,203	4 ± 7	-
Ankle-Foot	910	3 ± 6	-
Thigh	708	2 ± 5	-
Unknown	562	2 ± 5	-
Upper Limbs	493	2 ± 5	-
Elbow	461	2 ± 5	-
Pelvic-Hip	371	1 ± 5	-
Upper Arm	279	1 ± 5	-
Lower Leg	298	1 ± 5	-
Forearm	55	1 ± 5	-
Total	29,152	100	554

[†] 68th percentile confidence interval.

[‡] Sample size too small to calculate confidence intervals.

Table 29. Estimated occupant involvement by body region injured and type of object struck – all injury severities.

Body Region	**Type of Object Struck** †			**Total**
	Narrow Freq.	**Broad** Freq.	**Other** Freq.	Freq.
Face	4,638	862	971	6,471
Head-Skull	4,412	331	520	5,263
Neck-Cerv.Spine	1,124	2,278	325	3,727
Chest	1,713	0	237	1,950
Abdomen	409	0	19	428
Whole Body	95	124	75	294

† Sample size too small to calculate confidence intervals.

areas which have AIS scores greater than three – head-skull, chest, and abdomen – the majority of the injuries were caused by narrow objects. The most frequent object struck for neck-cervical spine injuries and whole body injuries were broad objects.

The data in table 30 seem to indicate that the worst accidents could have involved an occupant hitting an exterior object directly. A pole intruding into the passenger compartment would be coded as UNKNOWN-OBJECT-IN-ENVIRONMENT. The majority of injuries with AIS greater than three in this sample were to the head, and the type of object most frequently struck was narrow. It was shown in chapter 3 that most of the narrow objects were also tall, and in the previous section that most of the severe injuries occurred at the passenger compartment. These two findings are consistent with the large number of serious head injuries since a side-impact, passenger-compartment collision with a tall, narrow object would most likely cause damage to the upper body. Even though the neck-cervical spine area and whole body area account for relatively few serious injuries, it is still interesting that most of the injuries in these areas were caused by broad objects. A possible explanation for this may be that the broad object collisions were more often sideswipes. A collision of this type would cause the occupant to move forward as well as sideways, thus causing damage to the neck-spine when wearing a seat belt and whole body damage when not properly restrained.

INJURY SOURCES

The data in the previous sections seems to suggest that the most severe injuries in side-impact collisions are a result of an occupant directly striking an exterior object. This section uses the NASS data to determine which objects inside or outside the vehicle

Table 30. Estimated occupant involvements by source of injury.

Injury Source	**All Injuries**		**MAIS over3** [‡]
	Freq.	Percent [†]	Freq.
Unknown Source	10,748	38 ± 18	87
Unknown Object in Environment	74	0 ± 5	74
Side Hardware	978	3 ± 6	72
Window Glass/Frame	832	3 ± 6	69
A Pillar	636	2 ± 5	69
Non-Contact Injury	3,556	12 ± 12	50
Steering Assembly	1,490	5 ± 8	39
Side Interior	1,807	6 ± 9	37
Roof Side Rails	321	1 ± 5	24
Floor Trans.Lever	187	1 ± 5	19
Seat Back Supp.	1,004	4 ± 7	14
Windshield	3,082	11 ± 11	-
Instrument Panel	2,004	7 ± 9	-
Mirror	435	2 ± 5	-
Roof/Conv.Top	411	1 ± 5	-
Belt Restraint System	273	1 ± 5	-
Other	752	3 ± 6	-
Total	28,590	100	554
Missing	562		0

[†] 68th percentile confidence interval.

[‡] Sample size too small to calculate confidence intervals.

actually were the source of injury. The tables in this section are also all single-event collisions for the same reasons as in the previous section. Table 30 is a listing of those objects which caused injury in the judgement of the accident investigator. It also shows those objects which caused injuries with an AIS greater than three. Unfortunately, the cause of the injuries was unknown in 38 percent of the cases. The second leading cause of injury was a non-contact injury such as subdural hematoma or whip-lash. The two most common known sources of contact injury were the windshield and the instrument panel; both of which are in front of the occupant, not on the side.

When considering injuries with AIS's over three, the types of objects responsible for these serious injuries differ from those causing injuries of all severities. Again, the small sample size limits the confidence in the $AIS > 3$ column. Other than the unknown sources of injury, the largest source of injury is from an outside object in the environment. In fact, all of the injuries caused by an exterior object had $AIS > 3$, and none of these occupants were ejected. This is consistent with the theory described in the preceding sections that the most serious injuries are due to objects outside the vehicle intruding into the passenger compartment. The other main sources of serious injury include the side hardware, the A pillar, and the window glass or frame. Only three of the objects which caused AIS's above three are not on the side. These three – the steering assembly, seat back support, and floor transmission lever – together account for only 72 of the 554 serious injuries and could be struck by the far-side occupants while crossing the passenger compartment. This list of injury sources seems to indicate that the most harmful types of side impacts are those in which the direction of the force of impact is close to 90 degrees from the longitudinal axis of the vehicle. This is consistent with the findings that collisions in which the damage is distributed along the entire length of the vehicle, (e.g., sideswipes), do not seem to cause serious injuries.

DEFORMATION MEASUREMENTS

Intuitively, the amount of damage to the vehicle would seem to be a good predictor of occupant injury. Two variables quantitatively measure the amount of damage to the vehicle. The first one, the MAGNITUDE-OF-INTRUSION, measures the *interior* deformation. The second variable, CRUSH, measures the exterior deformation. The MAGNITUDE-OF-INTRUSION is a measure of how much an interior component of the vehicle has intruded into the occupant compartment. The vehicle components that would intrude upon the passenger in side impacts are the A-pillar, the B-pillar, roof rail, sill, and the door panel. The other variable, CRUSH, is a measure of exterior damage. In the NASS data collection process, there are six measurements taken directly of the depth of the damaged area. For the purposes of this study, the largest one was called CRUSH. In certain accidents these measurements are later used in a computer program called CRASH3 to estimate velocity changes. Although these measurements are taken for nearly every accident, they are not recorded in the NASS data unless this program is run; therefore, a large number of CRUSH variables are missing from the NASS data. Because many of the variables in this section were not coded, the sample size is quite small. The extrapolated NASS numbers have not been used in this section because they have little meaning for very small sample sizes. The tables in this section use the unextrapolated, or "raw," NASS data. The sample sizes were also too small to determine confidence intervals, so percents are not included. All of the tables in this section include only single-event collisions.

Magnitude of Intrusion

Table 31 shows the relationship in the sample of intrusion on occupant injury. No occupant in the study sample had an AIS over 3 without at least 50 mm of intrusion. The majority of those with AIS's above 3 were in collisions with intrusion of over 150 mm. Despite

Table 31. Occupant involvements by magnitude of intrusion and MAIS.

Magnitude of Intrusion	**Maximum Abbreviated Injury Score**				**Total**
	0	**1,2,or3**	**4,5,or6**	**Unknown**	
None	157	119	0	2	278
0-50 mm	7	16	0	1	24
50-150 mm	17	51	2	4	74
Over 150 mm	21	126	17	12	176
Missing					294

Table 32. Magnitude of intrusion by impact location for occupants with maximum AIS above 3.

Impact Location	**Magnitude of Intrusion** ‡		**Total**
	50-150 mm Freq.	**Over 150 mm** Freq.	Freq.
D	2	1	3
P	0	9	9
Y	0	6	6
Z	0	1	1
Total	2	17	19
Missing			73

‡ Sample Size too small to calculate confidence interval.

nearly a third of the cases not being coded, two surprising outcomes are evident: (1) Occupants can be seriously injured with little intrusion and, (2) occupants may be uninjured even with over 150 mm of intrusion. These two observations might indicate that some intrusion is necessary for high AIS's, but other conditions must also be met for there to be serious injury.

Another factor that would seem to add to the seriousness of intrusion is the location of impact. Table 32 shows the magnitude of intrusion versus the location of impact for those occupants in single event collisions whose MAIS's were above 3. All the passenger compartment collisions had over 150 mm of intrusion. In fact, of the four types of impacts, those that were distributed along the entire length of the vehicle were the only ones which did not have at least 150 mm of intrusion to severely(MAIS over 3) injure the occupants.

A comparison was also made between near-side and far-side impacts. Surprisingly, the same amount of intrusion appears to have caused roughly the same degree of injury for

Table 33. Occupant involvement by Crush and MAIS.

Crush ‡	**No Injury** Freq.	$MAIS \leq 3$ Freq.	$MAIS > 3$ Freq.	**Total** Freq.
0-125 mm	42	47	0	89
126-250 mm	21	67	2	90
251-500 mm	16	51	4	71
501-750 mm	6	17	1	24
751-1000 mm	0	11	4	15
1001-1250 mm	0	3	1	4
Over 1250 mm	0	2	0	2
Missing/Unk.				549

‡ Sample size too small to calculate confidence intervals.

both near- and far-side collisions. This seems to indicate that, even though injuries increased with magnitude of intrusion, it may not have been the intrusion of interior components that caused the injuries. The magnitude of intrusion may simply be a measure of total energy rather than the cause of injury. Occupants in high energy impacts may be more likely to be injured.

Crush

The CRUSH is also an indication of the amount of energy that was absorbed by the vehicle. Table 33 lists MAIS by the amount of crush. Because many of the cases were not coded, the numbers were not multiplied by the weights to give estimates of the number of occupants in these cases (i.e., only the raw numbers were used). Despite the large number of missing cases, some trends in the data seem reasonable. The severity of injury was distributed similarly in the range from 125 to 750 mm, with the majority of occupants having injury scores less than 3. Injuries begin appearing in the sample with just 150 mm of crush. With over 750 mm of crush, the occupant was always injured, and was severely injured in 1 of 4 collisions in this data sample. Both MAGNITUDE-OF-INTRUSION and CRUSH appear to be related to the severity of injury. As the guardrail example showed, there are other factors, such as location of impact and type of object, that may also play an important role in injury causation.

Table 34. Velocity statistics in passenger compartment collisions.

Velocity Type	Maximum Velocity km/h	Minimum Velocity km/h	Mean Velocity km/h	Standard Deviation
Lateral	62	1	24	17
Longitudinal	38	0	11	10
Total	67	1	29	17

IMPACT CONDITIONS

The three primary measures of impact conditions are vehicle speed, angle of impact, and yaw angle. This section discusses typical yaw and impact angles and velocities in side-impact collisions. The data in this section will be limited to single-event collisions in which the damage is located at the passenger compartment. This type of collision was selected because most of the incapacitating and fatal injuries seemed to occur at this location. An understanding of the characteristics of passenger compartment collisions is important for reducing serious injuries and deaths. Because of the large number of missing variables in this section the numbers all represent "raw" NASS counts, not estimates of the total accident population. The percentages are not included because the small sample size made computing confidence intervals impossible.

Impact Velocity

Velocity measurements in the NASS data are obtained from a computer program called CRASH3. CRASH3 uses damage measurements to estimate the changes in lateral, longitudinal, and total velocity (the velocity in the direction of the force of impact). For various reasons, the CRASH3 program is oftentimes not run. When the program is not used, the variables are left blank. Along with the large number of missing cases, there is also some doubt about the reliability of the CRASH3 program to accurately predict the velocity changes. The predicted values deviate from the actual but are neither consistently above or below the true values. The predicted values are more inaccurate for higher velocities. Because of the lack of accuracy in CRASH3, the velocity values in this section should be used with great caution. In single-event passenger-compartment side-impact collisions 23 of the 106 cases (30 percent) were not coded. The information in this section is therefore simply an interesting set of anecdotal data that cannot be related reliably to national trends.

Despite the problems with estimating vehicle speed, some trends in the sample are worth pointing out. Table 34 shows the gross statistics on the three change in velocity variables: total, longitudinal, and lateral ΔV. Side impact collisions seem to be characterized by relatively low changes in velocities. This does not necessarily mean that the vehicle is traveling at a low rate of speed prior to the accident; a high velocity may be what caused the driver to lose control of the vehicle. When a vehicle begins spinning, which is necessary for side impact, the forward velocity is transformed into lateral and rotational motion. The vehicle then has a velocity component in both the longitudinal and lateral directions. To travel sideways a vehicle must slide laterally on its wheels. Motion in this direction dissipates a great deal of energy and slows the vehicle down quickly. The average lateral velocity change in the sample upon impact was 24 km/h with a standard deviation of 17 km/h. The mean longitudinal and total velocity changes were 11 and 29 km/h respectively. Since it is difficult to achieve high velocities in the lateral direction, it is not surprising that these values are small. As expected, the lateral velocity is larger than the longitudinal because these are collisions which damage the passenger compartment only. Collisions with large longitudinal velocities would most likely be sideswipes and would therefore cause damage to be distributed over the entire side of the vehicle.

Table 35 gives the change in velocity versus MAIS for lateral, longitudinal, and total velocities. This table shows that 26 of the 83 lateral velocity changes were under 10 km/h, and 68 were less than 40 km/h. Five of the 8 occupants with an $AIS > 3$ were in vehicles with lateral velocities greater than 40 km/h. This is interesting because only 15 of the 83 cases have lateral velocities over this speed. As lateral velocities increase, the chance of being severely injured appeared to increase in this anecdotal sample.

The no injury and minor injury accidents occurred mostly at lower total velocity changes, whereas the high injury accidents appeared to occur when the total velocity change was greater than 30 km/h. Degree of injury appeared to be related to the change in lateral and total velocities. By contrast, most of the high AIS were in collisions with changes in longitudinal velocity less than 10 km/h. Low longitudinal velocities seemed to be related to large lateral velocities.

Direction of Force

The DIRECTION-OF-FORCE is a variable in the NASS data which indicates the angle between the forward direction of the vehicle and the direction of the force of impact. Figure 11 shows how this angle is measured using a guardrail as the object struck. This variable in the NASS data is not coded as an angle, but as a clock direction with 12 o'clock being impacts with a DIRECTION OF FORCE within ± 15 degrees of the front of the vehicle. Using clock directions reduces the precision of the results since the angles are limited to 30 degree increments.

Table 35. Velocity change versus MAIS in passenger compartment collisions.

CHANGE IN LATERAL VELOCITY (km/h) ‡

Maximum Abbreviated Injury Score

Velocity	$MAIS \leq 1$ Freq.	$2 \leq MAIS \leq 3$ Freq.	$MAIS > 3$ Freq.	Unknown Freq.	Total Freq.
0-10	24	2	0	0	26
11-20	7	4	1	1	13
21-30	13	1	1	1	16
31-40	5	7	1	0	13
Over 40	3	7	5	0	15
Total	52	21	8	2	83
Missing					23

CHANGE IN LONGITUDINAL VELOCITY (km/h) ‡

Maximum Abbreviated Injury Score

Velocity	$MAIS \leq 1$ Freq.	$2 \leq MAIS \leq 3$ Freq.	$MAIS > 3$ Freq.	Unknown Freq.	Total Freq.
0-10	37	10	5	2	54
11-20	8	5	1	0	14
21-30	4	3	1	0	8
31-40	3	3	1	0	7
Total	52	21	8	2	83
Missing					23

CHANGE IN TOTAL VELOCITY (km/h) ‡

Maximum Abbreviated Injury Score

Velocity	$MAIS \leq 1$ Freq.	$2 \leq MAIS \leq 3$ Freq.	$MAIS < 3$ Freq.	Unknown Freq.	Total Freq.
0-10	6	0	0	0	6
11-20	22	6	1	1	30
21-30	11	1	1	1	14
31-40	6	5	1	0	12
41-50	7	2	1	0	10
Over 50	0	7	4	0	11
Total	52	21	8	8	83
Missing					23

‡ Sample size too small to calculate confidence intervals.

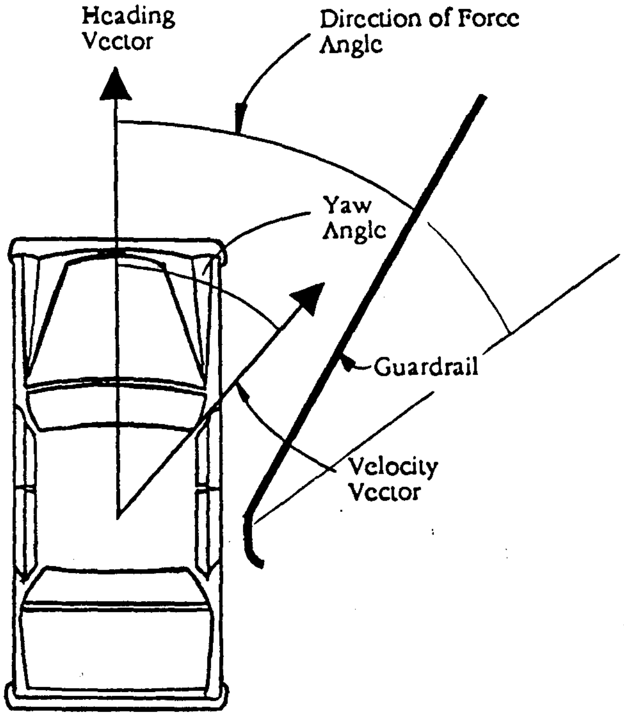


Figure 11. Definition of direction of force and definition of yaw angle.

Figure 12 shows the number of occupants who were involved in passenger-compartment collisions with the indicated impact angles. All the clock directions are combined on one side of the vehicle to keep the impact angles between 0 and 180 degrees. Seventy-eight of the 106 collisions occurred between 45 and 105 degrees. This agrees with the change in velocity data which indicated the lateral velocities were greater than the longitudinal velocities for passenger compartment collisions.

The severity of injury for different impact angles is shown in table 36. Not only did 43 of the 106 collisions occur at 75 to 105 degrees, 6 of the 9 MAIS scores over 3 were in this range. When impact angles are under 45 degrees or over 105 degrees they appeared less likely to result in serious injury. Because narrow object collisions with a DIRECTION-OF-FORCE between 45 and 105 degrees are the type that is most likely to result in an occupant hitting an exterior object, it is understandable that impacts in this range are the only ones in this sample that resulted in MAIS scores over 3. Another factor that contributes to the harmfulness of collisions in this range is the lack of restraint in the lateral direction. Because seat belts are ineffective in the lateral direction there is a much greater chance for injury in accidents with the DIRECTION-OF-FORCE between 45 and 105 degrees.

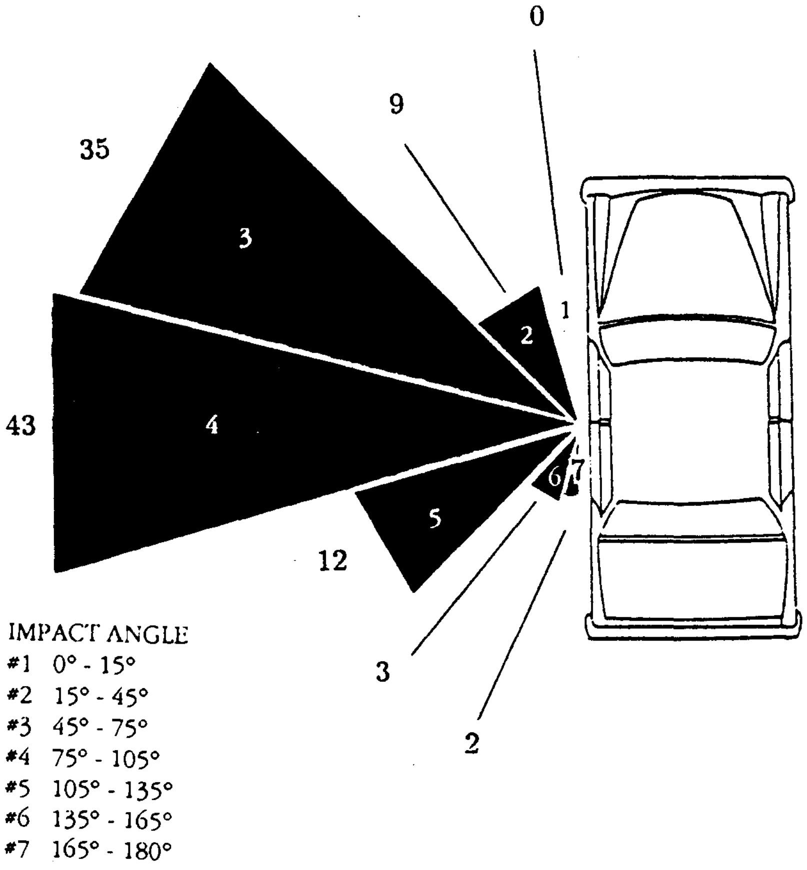


Figure 12. Distribution of impact angles in passenger compartment collisions.

Table 36. Angle of impact vs MAIS in
passenger compartment collisions.

Angle of	**Maximum Abbreviated Injury Score** ‡			
of Impact	$MAIS = 0$	$1 \leq MAIS \leq 3$	$MAIS > 3$	**Unknown**
Degrees	Freq.	Freq.	Freq.	Freq.
0-15	0	0	0	0
15-45	2	6	0	1
45-75	12	19	3	1
75-105	8	27	6	2
105-135	4	8	0	0
135-165	3	0	0	0
165-180	1	1	0	0
No Shift	0	2	0	0
Total	30	63	9	4

‡ Sample size too small to calculate confidence intervals.

Yaw Angle

The yaw angle, as shown in figure 11, is the angle between the total velocity vector of the vehicle and the forward direction of the vehicle. It was calculated in this study by dividing the lateral velocity of the vehicle by the longitudinal velocity. Because it was derived from the velocity variables, there were a large number of missing values. All the cautions mentioned for the change of velocity values are also appropriate in this discussion. Figure 13 shows a table of the frequency of yaw angles. The angles were converted so they would be less than 90 degrees, where 90 degrees means all the velocity is in the lateral direction. Sixty-five of the 83 yaw angles were over 48 degrees. Side-impact, passenger-compartment collisions in this sample were characterized by large yaw angles, which means most of the velocity is in the lateral direction.

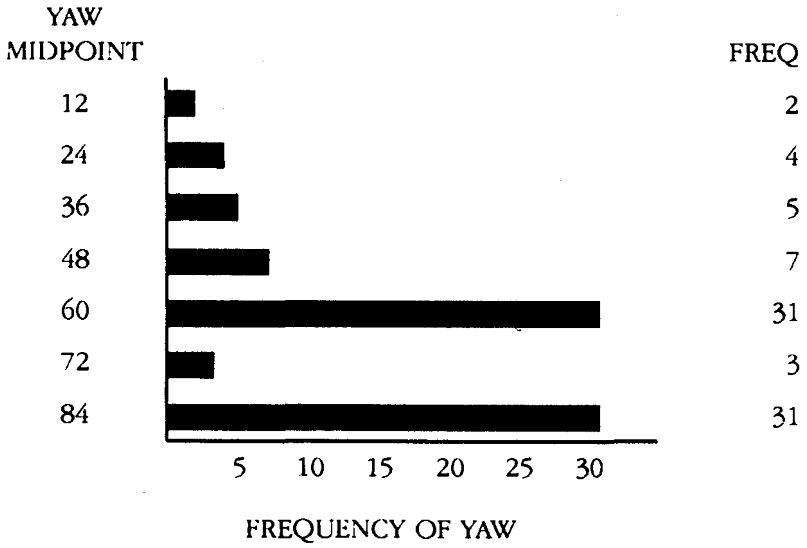


Figure 13. Yaw angles in passenger compartment collisions.

5 FIXED-OBJECT VERSUS VEHICLE-TO-VEHICLE SIDE IMPACTS

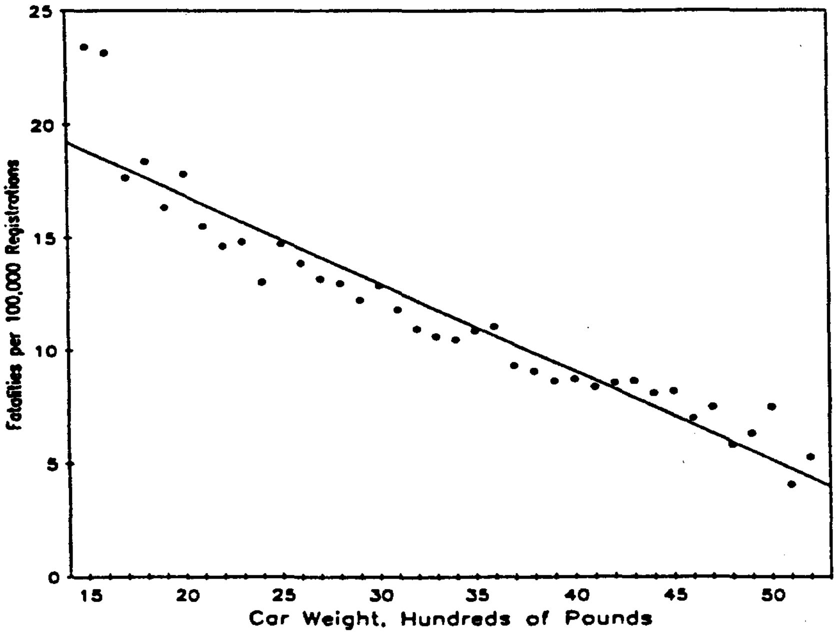
Much of the literature dealing with side-impact collisions groups vehicle-to-vehicle collisions with vehicle-to-fixed-object collisions, or neglects fixed-object collisions altogether. Although vehicle-to-vehicle collisions are the most common types of side-impact collisions, fixed-object collisions account for 37 percent of the serious to fatal injuries in all side-impact collisions.[16] The differences between these two types of side-impact collisions will be discussed in this section.

VEHICLE WEIGHT

Figure 6 showed that the weight of the vehicle had little, if any, effect on fatality rate. Partyka observes that this is a trait associated not only with fixed-object side impacts but with single-vehicle nonrollover accidents in general.[17] In contrast to this, the fatality rate in *multiple-vehicle* collisions is sensitive to vehicle weight. Figure 14 shows fatalities per 100,000 cars in multiple-vehicle accidents. It shows a decrease of 0.39 fatalities per 150-kg (100-lb) increase in car weight. The rate of decrease in fatalities for single-vehicle collisions, shown in figure 15, is only 0.02 per 150-kg (100-lb) increase in vehicle weight – not a statistically significant amount. Although these figures include frontal, rear, and side collisions, they demonstrate the contrast between the effect of weight on multiple-vehicle collisions and the effect of weight on single-vehicle collisions. The weight of the occupant's vehicle is an important factor in multiple-vehicle collisions, but apparently it is not in single-vehicle collisions, including side impacts with fixed objects.

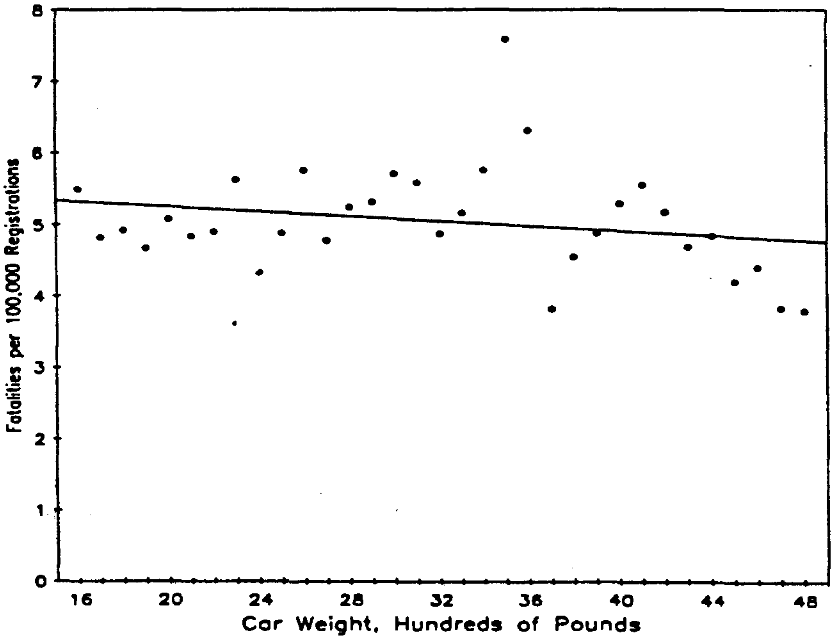
LOCATION OF IMPACT

Table 24 showed that the location of impact where the most severe injuries occurred in fixed-object collisions was the passenger compartment. In all types of side-impact accidents combined, however, Huelke notes that collisions involving occupants with AIS's greater than three have the most extensive damage at the "D" and "Y" locations.[4] A comparison of impact locations by Hartemann, et al., is shown in figures 16 and 17.[6] Figure 16 is a distribution of impact points for vehicle-to-vehicle side impacts and figure 17 is a distribution of vehicle-to-fixed-object side impacts. The distribution of impact points in multiple-vehicle collisions is more spread out. In this study, single-vehicle, side impacts with severe injuries were characterized by localized damage to the passenger compartment. Because other vehicles are broader than most fixed roadside objects, the impact area in vehicle-to-vehicle accidents is usually spread out over a larger area. It is important when automobile designers attempt to improve passenger safety in the lateral direction that they



1 lb = 0.453 kg

Figure 14. Fatalities per 100,000 cars in multiple vehicle accidents. [17]



1 lb = 0.453 kg

Figure 15. Fatalities per 100,000 cars in single vehicle nonrollover accidents.[17]

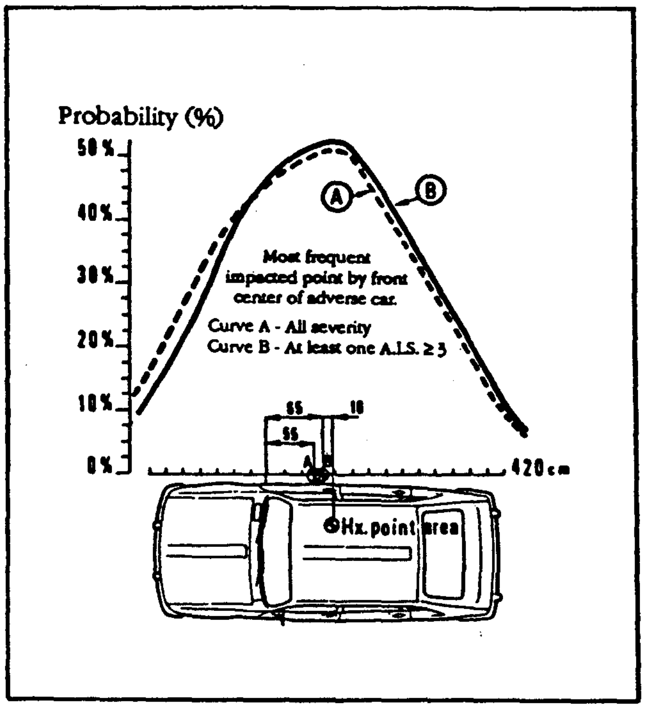


Figure 16. Distribution of impact along the side of the car in vehicle-to-vehicle accidents. [6]

realize there are a significant number of injuries that are due to impacts with localized damage to the passenger compartment.

BODY REGION

Studies by Partyka, Frost, and Dalmotas have all concluded that the body regions most likely to be injured in multiple-vehicle side impacts are the chest and abdomen.[18,19,20] Lozzi noted that car-to-car side impacts resulted in a combination of head, thoracic and abdominal injuries, but car-to-pole collisions produced mostly head injuries.[7] Lestina also notes the large number of head injuries in side-impact collisions.[3] Table 28 showed that head injuries are the most common body region severely injured in single-vehicle, fixed-object collisions in the NASS data studied. The two types of side-impact collisions have different injury mechanisms which result in different body regions being harmed.

INTRUSION

For side impacts in general, Huelke notes this:

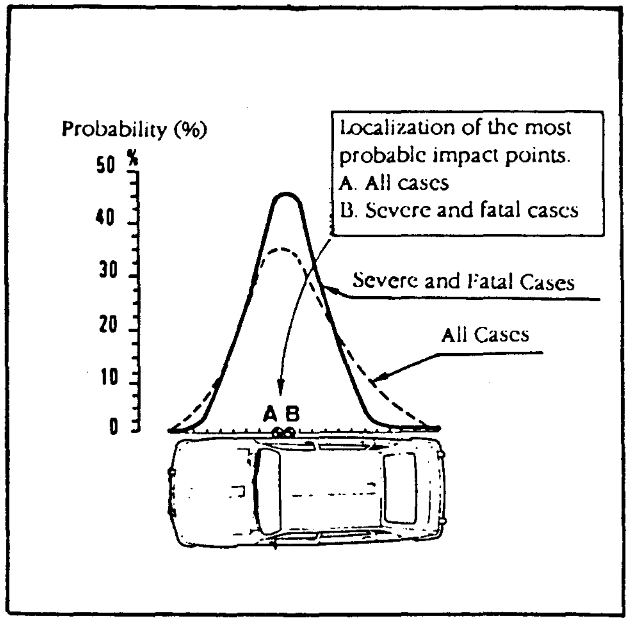


Figure 17. Distribution of impact along the side of the car in fixed-object accidents. [6]

Of all the various crash types - frontal, rollover, rear, etc, - the side impact is probably the most difficult to understand, to appreciate, and to "improve" for ***significant*** injury reductions. From field investigations of motor vehicle crashes it is difficult to show a direct correlation between door crush, intrusion, and direct injury in near side impacts.[21]

It is indeed difficult to find a correlation between magnitude of intrusion and injury for all side-impacts combined. Huelke further notes that significant intrusion without significant injury is not abnormal. This observation agrees with the findings in chapter 4. Intrusion did not seem to be a good predictor of injury in fixed-object, side impacts. In car-to-car, side-impact collisions, however, Hartemann, et al. observed that significant intrusion usually did correspond with high injury scores.[6] Although Hartemann attributes much of the difference to vehicle inner wall speed, the difference may also lie in the size difference between the objects struck. Intrusion due to a narrow object, such as a tree or pole, may be significant, but if it is not located adjacent to the occupant, it will probably not cause severe injury. If a broad object such as another automobile strikes the side of another car, the chances of the occupant being adjacent to the striking vehicle are much greater. Although both of these types of side collisions require significant intrusion to cause serious injury to occupants, a large amount of intrusion in fixed-object collisions is less likely to cause injury.

AGE AND TIME

Frost concluded that side-impact collisions usually involve older drivers, while frontal accidents involve younger drivers.[19] Her data is presented in a graph shown in figure 18. Note that the frontal crashes are limited to single vehicles but the side impacts are not. Fatality Facts published by The Insurance Institute for Highway Safety states that in 1989, occupants under the age of 35 accounted for 68 percent of all roadside-hazard fatalities while occupants over 65 accounted for only 6 percent of these fatalities.[22] In contrast, The Fatality Facts shows that fatality rates in all types of motor vehicle collisions combined are roughly equivalent for those under 35 and those over 65. These findings indicate that fatally injured occupants in fixed-object collisions are mostly young, while other types of collisions have a higher percentage of older drivers. The fatality rate per age group appears to be a function of the accident scenario more than a function of the location of impact. It appears that young drivers are most often involved in single-vehicle collisions, whereas older drivers are more likely to be involved in multiple-vehicle collisions.

Frost also notes that side-impact collisions of all types usually occur during daylight hours.[19] The Insurance Institute shows that 42 percent of all roadside hazard fatalities occur between 9 p.m. and 3 a.m.[22] Nearly 50 percent of fixed-object, side-impact collisions occur between 10 p.m. and 4 a.m. as shown in table 27. Fixed object collisions, including side impacts, usually occur at night.

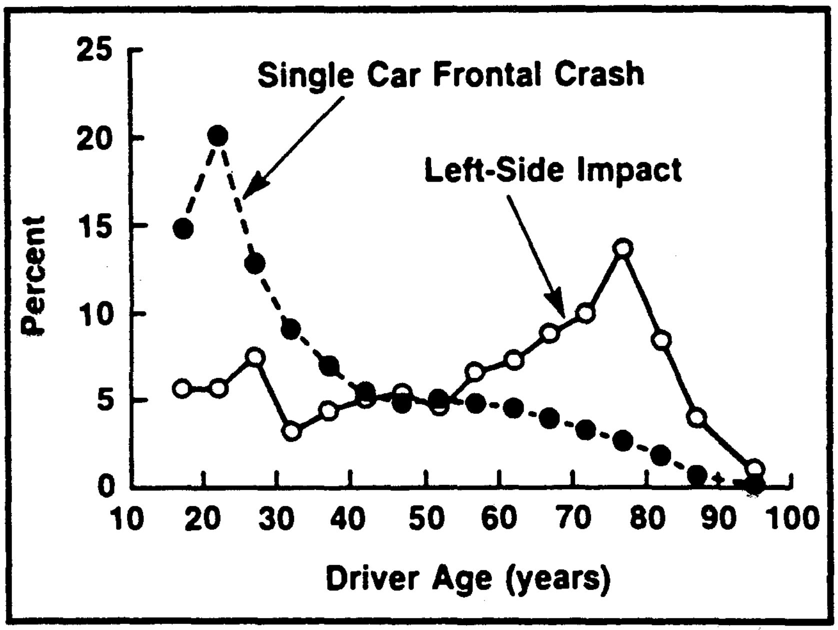


Figure 18. Driver age versus percent of occupants involved in single-vehicle frontal crashes and nearside side impacts with moderate damage.[19]

6 SUMMARY

A comparison of single-passenger-vehicle, side-impact collisions with fixed objects in the FARS and the NASS data revealed several characteristics of this type of accident. Most of the collisions involved narrow objects. The accidents that were most likely to cause a fatality were those that involved collisions with tall, narrow, rigid objects such as trees and utility poles. Occupants on the same side of the vehicle as the impact were most likely to sustain fatal injuries. A significant number of far-side occupants, however, were also fatally injured. The weight of the vehicle had little effect on the severity of injury in side-impact, fixed-object collisions. The majority of occupants in collisions with fixed objects, as well as the majority of fatalities, were on State, county, and local roads. Similarly, the most dangerous roadway alignment for side-impact, fixed-object collisions was curved. Most accidents occurred on dry surfaces. A large amount of deformation was observed in near- and far-side fatal impacts.

The NASS data allowed a more detailed examination of these accidents. Guardrail ends and transitions seemed to cause more fatalities and serious injuries than midsections. More incapacitating injuries occurred at the passenger compartment than in any other area. The head-skull body region had the most $AIS > 3$ injuries, and these injuries were usually incurred in collisions with narrow objects. The source of many of the severe injuries was an unknown object in the environment. Although there were small sample sizes for deformation characteristics and impact conditions, it appeared that large amounts of crush and large lateral velocity changes corresponded to high injury scores but severe injuries were also observed at low speeds and with little deformation. Most of the severe injuries had impact angles between 75 and 105 degrees, and yaw angles greater than 48 degrees. Most side-impact, fixed-object accidents occurred between 8 p.m. and 4 a.m and involved young occupants.

Finally, although fixed-object collisions represent only one-third of the side-impact problem, they result in more serious injury than other types of side impacts. The fixed-object collision differs from the multiple-vehicle side impact in the effects of vehicle weight, injury source, injured body region, age of the occupants, and time of the accident. For improvements in all side-impact collisions, the fixed-object collisions need to be treated differently than the vehicle-to-vehicle collisions.

APPENDIX A

SAS ANALYSIS PROGRAMS

```
*----------------------------------------------------
        MASTER.SAS
        This program combines all the programs required
        for the FARS data for years 1980-1985.
-----------------------------------------------------;
      libname library '/nfs/secfs/tmp/accident';
options linesize = 90;
        options pagesize = 70;
      dm 'zoom off;output;clear;wdef 2 1 24 80' output;

      data svfat;
        set library.svfat;
        where (YEAR between 80 and 85);

      proc format;
value vtfmt
1-11='PASSENGER VEHICLE'
12,13,40-69='UTILITY VEHICLE'
30-39='BUS'
20-29='MOTORCYCLE'
70-79='TRUCK'
80-99='OTHER';

*----------------------------------------------------------
     The tables created in this section are
     explained in the title lines.
-----------------------------------------------------------;

      proc freq data=svfat;
        format BODY_TYP vtfmt.;
        tables M_HARM*BODY_TYP / nopercent norow;
        title1 "MOST HARMFUL EVENT IN SIDE IMPACTS WITH";
        title2 "FIXED ROADSIDE OBJECTS BY VEHICLE TYPE";
title3 "1980-1985 FARS";

      proc freq data=svfat;
        tables M_HARM /list;
```

```
          where (1<=BODY_TYP<=11);
          title1 "LIST MOST HARMFUL EVENTS IN SINGLE VEHICLE";
          title2 "PASSENGER VEHICLE, SIDE IMPACT, FIXED ROADSIDE OBJECT";

        proc freq data = svfat;
        tables M_HARM*ROLLOVER;
        where (1<=BODY_TYP<=11);
        title1 "MOST HARMFUL EVENT BY ROLLOVER";
        title2 "    SIDE IMPACT ONLY";

        proc freq data = SVFAT;
        tables M_HARM*CL_TWAY;
        where (1<=BODY_TYP<=11);
        title1 "MOST HARMFUL EVENT BY CLASS TRAFFICWAY";
        title2 "    SIDE IMPACT ONLY";

        proc freq data = SVFAT;
        tables ALIGNMNT /list;
        where (1<=BODY_TYP<=11);
        title1 "   ROADWAY ALIGNMENT";
        title2 "    SIDE IMPACT ONLY";

        proc freq data = SVFAT;
        tables SUR_COND;
        where (1<=BODY_TYP<=11);
        title1 "SURFACE CONDITION DISTRIBUTION ";
        title2 "    SIDE IMPACT ONLY";

        proc freq data=svfat;
          tables M_HARM*DEFORMED;
          where (1<=BODY_TYP<=11);
          title1 "DEFORMATION EXTENT BY OBJECT STRUCK"
title2 "IN SIDE-IMPACT FIXED-OBJECT COLLISIONS"
          title3 "         ALL VEHICLES";

      * --------------------------------------
      This section creates a data set auto which
      includes only those variables needed to find
      vehicle weight and length.
      -------------------------------------------- ;
```

```
      data auto;
       set svfat (keep=WHLBS_SH VIN_WGT M_HARM IMPACT2 BODY_TYP);
where(BODY_TYP between 1 and 11);

         if (WHLBS_SH = 0) then BASE=999;
         if (0 < WHLBS_SH < 840) then BASE =84;
         if (840 <= WHLBS_SH < 900) then BASE=90;
         if (900 <= WHLBS_SH < 960) then BASE=96;
         if (960 <= WHLBS_SH < 1020) then BASE=102;
         if (1020 <= WHLBS_SH < 1080) then BASE=108;
         if (1080 <= WHLBS_SH < 1140) then BASE=114;
         if (1140 <= WHLBS_SH < 1200) then BASE=120;
         if (1200 <= WHLBS_SH < 1260) then BASE=126;
         if (1260 <= WHLBS_SH < 1320) then BASE=132;
         if (1320 <= WHLBS_SH < 1380) then BASE=138;
         if (1380 <= WHLBS_SH < 1440) then BASE=144;
         if (1440 <= WHLBS_SH < 1500) then BASE=150;
         if (1500 <= WHLBS_SH < 1560) then BASE=156;
         if (1560 <= WHLBS_SH < 1620) then BASE=162;
         if (1620 <= WHLBS_SH < 1680) then BASE=168;
         if (1680 <= WHLBS_SH < 1740) then BASE=174;
         if (1740 <= WHLBS_SH < 9000) then BASE=900;
         if (WHLBS_SH >=9000) then BASE=999;

        if (VIN_WGT < 1300) then WEIGHT=1300;
        if (1300 <= VIN_WGT < 1500) then WEIGHT=1400;
        if (1500 <= VIN_WGT < 1700) then WEIGHT=1600;
        if (1700 <= VIN_WGT < 1900) then WEIGHT=1800;
        if (1900 <= VIN_WGT < 2100) then WEIGHT=2000;
        if (2100 <= VIN_WGT < 2300) then WEIGHT=2200;
        if (2300 <= VIN_WGT < 2500) then WEIGHT=2400;
        if (2500 <= VIN_WGT < 2700) then WEIGHT=2600;
        if (2700 <= VIN_WGT < 2900) then WEIGHT=2800;
        if (2900 <= VIN_WGT < 3100) then WEIGHT=3000;
        if (3100 <= VIN_WGT < 3300) then WEIGHT=3200;
        if (3300 <= VIN_WGT < 3500) then WEIGHT=3400;
        if (3500 <= VIN_WGT < 3700) then WEIGHT=3600;
        if (3700 <= VIN_WGT < 3900) then WEIGHT=3800;
        if (3900 <= VIN_WGT < 4100) then WEIGHT=4000;
```

```
        if (4100 <= VIN_WGT < 4300) then WEIGHT=4200;
        if (4300 <= VIN_WGT < 4500) then WEIGHT=4400;
        if (4500 <= VIN_WGT < 4700) then WEIGHT=4600;
        if (4700 <= VIN_WGT < 4900) then WEIGHT=4800;
        if (4900 <= VIN_WGT < 5100) then WEIGHT=5000;
        if (5100 <= VIN_WGT < 5300) then WEIGHT=5200;
if (5300 <= VIN_WGT < 9999) then WEIGHT = 9000;

       proc means;
  var WEIGHT BASE;


      proc freq data = auto;
      format base basefmt.;
      tables BASE / list;
      title1 "DISTRIBUTION OF PASSENGER CAR WHEEL BASES (SHORT) ";
      title2 "FOR SIDE-IMPACT FIXED-OBJECT FATALITIES";

      proc freq data = auto;
      tables WEIGHT / list;
      title1 "DISTRIBUTION OF PASSENGER CAR VIN WEIGHT";
      title2 "FOR SIDE-IMPACT FIXED-OBJECT FATALITIES";

*----------------------------------------------------
        This section creates a data set named direc
        which includes those variabls needed for
        finding near- and far-side characteristics.
----------------------------------------------------;

      data direc;
        set svfat;
near=0;
if ((IMPACT2 in (8 9 10)) and (SEAT_POS in (11 21 31 41 ))) then near=1;
if ((IMPACT2 in (2 3 4)) and (SEAT_POS in (13 23 33 ))) then near=1;
if ((IMPACT2 in (2 3 4)) and (SEAT_POS in (11 21 31 ))) then near=2;
if ((IMPACT2 in (8 9 10)) and (SEAT_POS in (13 23 33 ))) then near=2;
        where (1<=BODY_TYP<=11);

      proc format;
value nearfmt 0='OTHER' 1='NEAR-SIDE' 2='FAR-SIDE';
```

```
      proc freq data=direc;
where SEAT_POS in (11 13 21 23 31 33);
        tables IMPACT2*SEAT_POS;
        title1 "IMPACT DIRECTION BY SEATING POSITION"
title2 "IN SIDE-IMPACT FIXED-OBJECT COLLISIONS"
        title3 "         ALL VEHICLES";

      proc freq data=direc;
format near nearfmt.;
        tables IMPACT2*NEAR;
        title1 "NEARSIDE OCCUPANT FATALITIES BY IMPACT DIRECTION"
title2 "IN SIDE-IMPACT FIXED-OBJECT COLLISIONS"
        title3 "         ALL VEHICLES";


        run;
```

```
*----------------------------------------------------
        NASS.SAS
---------------------------------------------------

     This first section has the programs used
     in chapter III that were compared to
     the FARS data.
-----------------------------------------------------;

      libname library '/nfs/secfs/tmp/accident';
options linesize = 90;
        options pagesize = 70;
      dm 'zoom off;output;clear;wdef 2 1 24 80' output;

      data svfat;
        set library.nass;
        format FEDAID FEDAID.;
        where (IMPTYPE between 2 and 3) and (OBJCONT1^=69);
        QRATWGT=RATWGT/4;

      proc format;
value vtfmt
1-11='PASSENGER VEHICLE'
12,13,40-69='UTILITY VEHICLE'
30-39='BUS'
20-29='MOTORCYCLE'
70-79='TRUCK'
80-99='OTHER';

      proc freq data=svfat;
        format BODYTYPE vtfmt.;
        tables BODYTYPE / list;
        weight QRATWGT;
        title1 "LIST OF VEHICLE TYPE IN SIDE-IMPACTS WITH";
        title2 "FIXED ROADSIDE OBJECTS";

      proc freq data=svfat;
        tables OBJCONT1 /list;
        weight QRATWGT;
        where (1<=BODYTYPE<=11);
```

```
    title1 "LIST OF MOST HARMFUL EVENTS IN SINGLE VEHICLE";
    title2 "PASSENGER VEHICLE, SIDE IMPACT, FIXED ROADSIDE OBJECT";

  proc freq data = svfat;
  tables ROLLOVER/ list;
  weight QRATWGT;
  where (1<=BODYTYPE<=11);
  title1 "MOST HARMFUL EVENT BY ROLLOVER";
  title2 "PASSENGER CARS& SIDE IMPACT ONLY";

  proc freq data = SVFAT;
  tables CLTWAY /list;
  weight QRATWGT;
  where (1<=BODYTYPE<=11);
  title1 "MOST HARMFUL EVENT BY CLASS TRAFFICWAY";
  title2 "PASSENGER CARS SIDE IMPACT ONLY";

  proc freq data = svfat;
  tables ALIGNMNT /list;
  weight QRATWGT;
  where (1<=BODYTYPE<=11);
  title1 "   ROADWAY ALIGNMENT";
  title2 "    SIDE IMPACT PASSENGER CARS ONLY";

  proc freq data = svfat;
  tables SURCOND /list;
  weight QRATWGT;
  where (1<=BODYTYPE<=11);
  title1 "SURFACE CONDITION DISTRIBUTION ";
  title2 "PASSENGER CAR & SIDE IMPACT ONLY";
  footnote1;
  footnote2;

* --------------------------------------
  This section creates a data set, auto,
  which determines the vehicle base length and
  vin weight for vehicles involved.
------------------------------------------ ;
   data auto;
    set svfat;
```

```
where (BODYTYPE between 1 and 11);

        if (WHEELSHT=0) then BASE=999;
        if (0 < WHEELSHT < 84)then BASE=84;
        if (84 <= WHEELSHT < 90)then BASE=90;
        if (90 <= WHEELSHT < 96)then BASE=96;
        if (96 <= WHEELSHT < 102)then BASE=102;
        if (102 <= WHEELSHT < 108)then BASE=108;
        if (108 <= WHEELSHT < 114)then BASE=114;
        if (114 <= WHEELSHT < 120)then BASE=120;
        if (120 <= WHEELSHT < 126)then BASE=126;
        if (126 <= WHEELSHT < 132)then BASE=132;
        if (132 <= WHEELSHT < 138)then BASE=138;
        if (138 <= WHEELSHT < 144)then BASE=144;
        if (144 <= WHEELSHT < 150)then BASE=150;
        if (150 <= WHEELSHT < 156)then BASE=156;
        if (156 <= WHEELSHT < 162)then BASE=162;
        if (162 <= WHEELSHT < 168)then BASE=168;
        if (168 <= WHEELSHT < 174)then BASE=174;
        if (174 <= WHEELSHT < 900)then BASE=900;
        if (WHEELSHT >= 900)then BASE=999;

        if (CURBWGT < 013) then WEIGHT=1300;
        if (013 <= CURBWGT < 015) then WEIGHT=1400;
        if (015 <= CURBWGT < 017) then WEIGHT=1600;
        if (017 <= CURBWGT < 019) then WEIGHT=1800;
        if (019 <= CURBWGT < 021) then WEIGHT=2000;
        if (021 <= CURBWGT < 023) then WEIGHT=2200;
        if (023 <= CURBWGT < 025) then WEIGHT=2400;
        if (025 <= CURBWGT < 027) then WEIGHT=2600;
        if (027 <= CURBWGT < 029) then WEIGHT=2800;
        if (029 <= CURBWGT < 031) then WEIGHT=3000;
        if (031 <= CURBWGT < 033) then WEIGHT=3200;
        if (033 <= CURBWGT < 035) then WEIGHT=3400;
        if (035 <= CURBWGT < 037) then WEIGHT=3600;
        if (037 <= CURBWGT < 039) then WEIGHT=3800;
        if (039 <= CURBWGT < 041) then WEIGHT=4000;
        if (041 <= CURBWGT < 043) then WEIGHT=4200;
        if (043 <= CURBWGT < 045) then WEIGHT=4400;
        if (045 <= CURBWGT < 047) then WEIGHT=4600;
```

```
        if (047 <= CURBWGT < 049) then WEIGHT=4800;
        if (049 <= CURBWGT < 051) then WEIGHT=5000;
        if (051 <= CURBWGT < 053) then WEIGHT=5200;
if (CURBWGT >= 053) then WEIGHT = 5300;

near=0;
if (IMPTYPE=2) and (SEATPOS in (01 04 07 )) then near=1;
if (IMPTYPE=3) and (SEATPOS in (03 06 09 )) then near=1;
if (IMPTYPE=3) and (SEATPOS in (01 04 07 )) then near=2;
if (IMPTYPE=2) and (SEATPOS in (03 06 09 )) then near=2;

        if WHEELSHT>0 then dimls=DVD/(2.54*WHEELSHT);
        cmax=DVC1;
        if DVC2 > cmax then cmax = DVC2;
        if DVC3 > cmax then cmax = DVC3;
        if DVC4 > cmax then cmax = DVC4;
        if DVC5 > cmax then cmax = DVC5;
        if DVC6 > cmax then cmax = DVC6;

        if 0.85 >= dimls > 0.75 then impt=0.8;
        if 0.75 >= dimls > 0.65 then impt=0.7;
        if 0.65 >= dimls > 0.55 then impt=0.6;
        if 0.55 >= dimls > 0.45 then impt=0.5;
        if 0.45 >= dimls > 0.35 then impt=0.4;
        if 0.35 >= dimls > 0.25 then impt=0.3;
if 0.25 >= dimls > 0.15 then impt=0.2;
        if 0.15 >= dimls > 0.05 then impt=0.1;
        if 0.05 >= dimls > -.05 then impt=0.0;
        if -.05 >= dimls > -.15 then impt=-0.1;
        if -.15 >= dimls > -.25 then impt=-0.2;
        if -.25 >= dimls > -.35 then impt=-0.3;
        if -.35 >= dimls > -.45 then impt=-0.4;
        if -.45 >= dimls > -.55 then impt=-0.5;
        if -.55 >= dimls > -.65 then impt=-0.6;
        if -.65 >= dimls > -.75 then impt=-0.7;
        if -.75 >= dimls > -.85 then impt=-0.8;

        cmax = cmax/2.54;

        if 0<cmax<=2.5 then crush=1;
```

```
        if 2.5<cmax<=5 then crush=2;
        if 5 < cmax<=10 then crush=3;
        if 10 < cmax<=20 then crush=4;
        if 20 < cmax<=30 then crush=5;
        if 30 < cmax<=40 then crush=6;
        if 40 < cmax<=50 then crush=7;
        if 50 < cmax<=60 then crush=8;
        if 60 < cmax<=70 then crush=9;
        if 70 < cmax<=80 then crush=10;
        if cmax> 80 then crush=99;

time=time/3600;

      proc format;
value nearfmt 0='OTHER' 1='NEAR-SIDE' 2='FAR-SIDE';

       value timefmt
               0-2='12-2 am'
               2.01-4='2-4 am'
               4.01-6='4-6 am'
               6.01-8='6-8 am'
               8.01-10='8-10 am'
               10.01-12='10 am-12 pm'
               12.01-14='12-2pm'
               14.01-16='2-2pm'
               16.01-18='4-6pm'
               18.01-20='6-8pm'
               20.01-22='8-10pm'
               22.01-24='10pm-12am';

     value crfmt
           1='0-2.5 in'
           2='2.6 - 5 in'
           3='6-10 in'
           4='11-20 in'
           5='21-30 in'
           6='31-40 in'
           7='41-50 in'
           8='51-60 in'
           9='61-70 in'
```

```
          10='71-80 in'
          99='over 80';

      value magfmt
           0='None'
           1='< 5cm'
           2='5-15cm'
           3='>15cm';

value agefmt
  0-15='0-15'
  16-19='16-19'
  20-24='20-24'
  25-34='25-34'
  35-44='35-44'
  45-54='45-54'
  55-64='55-64'
  64-99='over 64';

     value ms2fmt
0='0'
1,2,3='1,2,3'
4,5,6='4,5,6'
7-9='UNKNOWN';

      proc freq data = auto;
      tables WEIGHT / list;
      weight QRATWGT;
      title1 "DISTRIBUTION OF PASSENGER CAR VIN WEIGHT";
      title2 "FOR SIDE-IMPACT FIXED-OBJECT FATALITIES";

      proc freq data=auto;
where SEATPOS in (01 03 04 06 07 09);
        tables SEATPOS*IMPTYPE;
        weight QRATWGT;
        title1 "IMPACT DIRECTION BY SEATING POSITION"
title2 "IN SIDE-IMPACT FIXED-OBJECT COLLISIONS"
        title3 "         ALL VEHICLES";

      proc freq data=auto;
```

```
format near nearfmt.;
        tables IMPTYPE*NEAR;
        weight QRATWGT;
        title1 "OCCUPANT INJURIES BY IMPACT DIRECTION"
title2 "IN SIDE-IMPACT FIXED-OBJECT COLLISIONS"
        title3 "         ALL VEHICLES";


*----------------------------------------------------------------------------

    These programs are for use in Chapter IV

  ----------------------------------------------------------------------------

      proc freq data=auto;
        tables INJSEV*MAIS;
        where (IMPTYPE between 2 and 3);
        weight QRATWGT;
        title1 "POLICE REPORTED INJURY BY MAIS";
        title2 "SINGLE VEHICLE, PASSENGER VEHICLE, SIDE IMPACT FIXED OBJECT";

      proc freq data=auto;
        tables OBJCONT1*INJSEV;
        weight qratwgt;
        where(IMPTYPE between 2 and 3);
        title1 "OBJECT CONTACTED VS POLICE REPORTED INJURY";
        title2 "S.V., P.V., SIDE, FIXED OBJECT";

      proc freq data=auto;
        tables SHL1*INJSEV;
        weight qratwgt;
        where (IMPTYPE between 2 and 3);
        title1 "LOCATION OF SIDE IMPACT BY INJURY SEVERITY";
        title2 "SINGLE VEHICLE, PASSENGER VEHICLE, SIDE IMPACT, FIXED OBJECT";

      proc freq data=auto;
        tables INJSEV /list;
        weight qratwgt;
        where (SHL1='P')and (IMPTYPE between 2 and 3);
        title1 "OBJECT CONTACTED VS POLICE REPORTED INJURY";
```

```
        title2 "S.V., P.V., SIDE, FIXED OBJECT";
        title3 "PASSENGER COMPARTMENT COLLISIONS";

     proc freq data=auto;
        format TIME timefmt.;
        tables TIME /list;
weight qratwgt;
        title1 "LIST OF TIMES IN S.V., P.V., SIDE, SINGLE EVENT";

     proc freq data=auto;
format AGE agefmt.;
tables AGE /list;
weight qratwgt;
title1 "AGE OF OCCUPANTS IN S.V., P.V., SIDE, SINGLE EVENT;"

*--------------------------------------------------
    This section creates a data set, scoll,
    that is used for body region and injury source.
    These are single event collisions.
------------------------------------------------;

      data scoll;
        set svfat;
        where (BODYTYPE between 1 and 11)
              and (VEHSEQ1=1)and (VEHSEQ2<1)and (OBJCONT2<0);


      proc format;
        value aisfmt 0='NO INJURY'
                     1='MINOR'
                     2='MODERATE'
                     3='SERIOUS'
                     4,5,6='>3'
                     7,9='UNKNOWN';

         value objfmt
           43,50,51,56,59,57,62,63,64,65,66,67='LONG. OBJECTS'
           32,33,34,35,36,37,38,39,40,41,42,44,58,60,61='NARROW OBJECTS'
           69='GROUND'
           45,47,48,49,52,53,54,55,68,71,72='OTHER';
```

```
 proc freq data=scoll;
   tables BODYREG1 /list;
   where BODYREG1^='0';
   weight qratwgt;
   title1 "BODY REGION INJURED OF THOSE INJURED";
   title2 "S.V., P.V., SIDE, FIXED OBJECT";
   title3 "SINGLE EVENT COLLISIONS";

 proc freq data=scoll;
   tables BODYREG1 /list;
   where BODYREG1^='0' and (3<AIS1<7);
   weight qratwgt;
   title1 "BODY REGION INJURED";
   title2 "S.V., P.V., SIDE, FIXED OBJECT";
   title3 "SINGLE EVENT COLLISIONS with AIS1>3";

proc freq data=scoll;
   format OBJCONT1 objfmt.;
   tables BODYREG1*OBJCONT1;
   weight qratwgt;
   where BODYREG1 ^='0';
   title1 "BODYREGION BY TYPE OF OBJECT";
   title2 "S.V., P.V., SIDE, FIXED OBJECT";
   title3 "SINGLE EVENT COLLISONS";

proc freq data=scoll;
   tables INJSOU1 /list;
   weight qratwgt;
   where INJSOU1^=0;
   title1 "LIST OF INJURY SOURCE OF THOSE INJURED";
   title2 "S.V., P.V., SIDE, FIXED OBJECT";
   title3 "SINGLE EVENT COLLISIONS";

proc freq data=scoll;
   tables INJSOU1 /list;
   weight qratwgt;
   where (3<AIS1<7);
   title1 "LIST OF INJURY SOURCE";
   title2 "S.V., P.V, SIDE, FIXED OBJECT";
```

```
         title3 "SINGLE EVENT COLLISIONS with AIS1>3";

*----------------------------------------------------------------------------
     The following programs use a data set called "svveh", which
     contains all side impact, single vehicle, fixed object, single
     event, passenger compartment collisions.
-----------------------------------------------------------------------------;

      data svveh;
        set scoll;
        where (SHL1 ='P');

        if YEAR=85 then DVLAT=DVLAT*1.61;
        if YEAR=85 then DVLONG=DVLONG*1.61;
        if YEAR=85 then DVTOTAL=DVTOTAL*1.61;
        if YEAR=85 then ENERGY=ENERGY*.01356;

        if (DVLONG^=0) then yaw=abs(57.296*(atan(DVLAT/DVLONG)));
        if (DVLONG=0) then yaw=90;

        DVLAT=abs(DVLAT*0.62);
        DVLONG=abs(DVLONG*0.62);
        DVTOTAL=DVTOTAL*0.62;

        if (20<=DOF1<=39) then DOF1=DOF1-20;
        if (40<=DOF1<=59) then DOF1=DOF1-40;
        if (60<=DOF1<=79) then DOF1=DOF1-60;
        if (80<=DOF1<=99) then DOF1=DOF1-80;

        if -45<=DVLAT < -40 then DVLAT = 8;
        if -40<=DVLAT < -35 then DVLAT = 7;
        if -35<=DVLAT < -30 then DVLAT = 6;
        if -30<=DVLAT < -25 then DVLAT = 5;
        if -25<=DVLAT < -20 then DVLAT = 4;
        if -20<=DVLAT < -15 then DVLAT = 3;
        if -15<=DVLAT < -10 then DVLAT = 2;
        if -10<=DVLAT < -5 then DVLAT = 1;
        if -5<=DVLAT <= 5 then DVLAT = 0;
        if 5 < DVLAT <=10 then DVLAT = 1;
        if 10 < DVLAT <=15 then DVLAT = 2;
```

```
if 15 < DVLAT <=20 then DVLAT = 3;
if 20 < DVLAT <=25 then DVLAT = 4;
if 25 < DVLAT <=30 then DVLAT = 5;
if 30 < DVLAT <=35 then DVLAT = 6;
if 35 < DVLAT <=40 then DVLAT = 7;
if 40 < DVLAT <=45 then DVLAT = 8;

if -45<=DVLONG < -40 then DVLONG = 8;
if -40<=DVLONG < -35 then DVLONG= 7;
if -35<=DVLONG< -30 then DVLONG= 6;
if -30<=DVLONG< -25 then DVLONG= 5;
if -25<=DVLONG< -20 then DVLONG= 4;
if -20<=DVLONG< -15 then DVLONG= 3;
if -15<=DVLONG< -10 then DVLONG= 2;
if -10<=DVLONG< -5 then DVLONG = 1;
if -5<=DVLONG<= 5 then DVLONG= 0;
if 5 < DVLONG<=10 then DVLONG= 1;
if 10 < DVLONG <=15 then DVLONG= 2;
if 15 < DVLONG<=20 then DVLONG= 3;
if 20 < DVLONG<=25 then DVLONG= 4;
if 25 < DVLONG<=30 then DVLONG= 5;
if 30 < DVLONG<=35 then DVLONG= 6;
if 35 < DVLONG<=40 then DVLONG= 7;
if 40 < DVLONG<=45 then DVLONG= 8;

if -45<=DVTOTAL < -40 then DVTOTAL = 8;
if -40<=DVTOTAL < -35 then DVTOTAL = 7;
if -35<=DVTOTAL < -30 then DVTOTAL = 6;
if -30<=DVTOTAL < -25 then DVTOTAL = 5;
if -25<=DVTOTAL < -20 then DVTOTAL = 4;
if -20<=DVTOTAL < -15 then DVTOTAL = 3;
if -15<=DVTOTAL < -10 then DVTOTAL = 2;
if -10<=DVTOTAL < -5 then DVTOTAL = 1;
if -5<=DVTOTAL <= 5 then DVTOTAL = 0;
if 5 < DVTOTAL <=10 then DVTOTAL = 1;
if 10 < DVTOTAL <=15 then DVTOTAL = 2;
if 15 < DVTOTAL <=20 then DVTOTAL = 3;
if 20 < DVTOTAL <=25 then DVTOTAL = 4;
if 25 < DVTOTAL <=30 then DVTOTAL = 5;
if 30 < DVTOTAL <=35 then DVTOTAL = 6;
```

```
        if 35 < DVTOTAL <=40 then DVTOTAL = 7;
        if 40 < DVTOTAL<=45 then DVTOTAL = 8;

        if 0<=ENERGY< 200 then ENERGY=100;
        if 200 <= ENERGY < 400 then ENERGY = 30000;
        if 400 <= ENERGY < 600 then ENERGY = 50000;
        if 600 <= ENERGY < 800 then ENERGY = 70000;
        if 800 <= ENERGY < 1000 then ENERGY = 90000;
        if 1000 <= ENERGY < 1200 then ENERGY = 110000;
        if 1200 <= ENERGY < 1400 then ENERGY = 130000;
        if 1400 <= ENERGY < 1600 then ENERGY = 150000;
        if 1600 <= ENERGY < 1800 then ENERGY = 170000;
        if 1800 <= ENERGY < 2000 then ENERGY = 190000;
        if 2000 <= ENERGY < 2200 then ENERGY = 210000;
        if 2200 <= ENERGY <=9997 then ENERGY = 999700;

        if (20<=DOF1<=39) then DOF1=DOF1-20;
        if (40<=DOF1<=59) then DOF1=DOF1-40;
        if (60<=DOF1<=79) then DOF1=DOF1-60;
        if (80<=DOF1<=99) then DOF1=DOF1-80;

      proc format;
        value doffmt
            0='NO SHIFT'
1,11='15-45 deg.'
2,10='45-75 deg.'
3,9 ='75-105 deg.'
4,8='105-135 deg'
5,7='135-165 deg'
  6='165-180 deg'
 12='0-15 deg'
            20-32='END SHIFT UP'
            40-52='END SHIFT DOWN'
            60-72='END/TOP RIGHT'
            80-92='END/TOP LEFT';

        value objfmt
          43,50,51,56,59,57,62,63,64,65,66,67='LONG.OBJECTS'
          32,33,34,35,36,37,38,39,40,41,42,44,58,60,61='NARROW OBJECTS'
          45,47,48,49,52,53,54,55,68,71,72='OTHER';
```

```
        value dvlatfmt
           0,1='0-10 mph'
           2,3='11-20 mph'
           4,5='21-30 mph'
           6,7='31-40 mph'
           8='41-45 mph';

        value dvlofmt
           0,1='0-10 mph'
           2,3='11-20 mph'
           4,5='21-30 mph'
           6,7='31-40 mph'
           8='41-45 mph';

        value dvtotfmt
           0,1='0-10 mph'
           2,3='11-20 mph'
           4,5='21-30 mph'
           6,7='31-40 mph'
           8='41-45 mph';

      value yawfmt
0-18='0-18'
18.01-30='18-30'
30.01-42='30-42'
42.01-54='42-54'
54.01-66='54-66'
66.01-78='66-78'
78.01-90='78-90';

      value maisfmt
0,1='0,1'
2,3='2,3'
4,5,6='4,5,6'
7-9='UNKNOWN';

     value ms2fmt
0='0'
1,2,3='1,2,3'
```

```
4,5,6='4,5,6'
7-9='UNKNOWN';


       proc means;
         var DVLAT DVLONG DVTOTAL ENERGY yaw;
         title1 "STATISTICS ON VARIABLES FOR S.V., P.V., SIDE (RAW)";
         title2 "SINGLE EVENT, PASSENGER COMPARTMENT";

      proc freq data=svveh;
         format DVLAT dvlatfmt. MAIS maisfmt.;
         tables DVLAT*MAIS;
         where SHL1='P';
         title1 "LATERAL DELTA V BY MAIS SCORES (RAW)";
         title2 "SINGLE VEH., PASSENGER VEH., SIDE, FIXED OBJ.";
         title3 "SINGLE COLLISION, PASSENGER COMPARTMENT";

      proc freq data=svveh;
         format DVLONG dvlofmt. MAIS maisfmt.;
         tables DVLONG*MAIS;
         where SHL1='P';
         title1 "LONGITUDINAL DELTA V BY MAIS SCORES (RAW)";
         title2 "SINGLE VEH., PASSENGER VEH., SIDE, FIXED OBJ.";
         title3 "SINGLE COLLISION, PASSENGER COMPARTMENT";

      proc freq data=svveh;
         format DVTOTAL dvtotfmt. MAIS maisfmt.;
         tables DVTOTAL*MAIS;
         where SHL1='P';
         title1 "TOTAL DELTA V BY MAIS SCORES";
         title2 "SINGLE VEH., PASSENGER VEH., SIDE, FIXED OBJ.";
         title3 "SINGLE COLLISION, PASSENGER COMPARTMENT";

      proc freq data=svveh;
         format DOF1 doffmt. MAIS ms2fmt.;
         tables DOF1*MAIS;
         where SHL1='P';
         title1 "DIRECTION OF FORCE VS MAIS (RAW)";
         title2 "SINGLE VEH., PASSENGER VEH., SIDE, FIXED OBJ.";
         title3 "SINGLE COLLISION, PASSENGER COMPARTMENT";
```

```
    proc freq data=svveh;
format yaw yawfmt.;
        tables yaw /list;
        where SHL1='P';
        title1 "YAW VS MAIS (RAW)";
        title2 "SINGLE VEH., PASSENGER VEH., SIDE, FIXED OBJ.";
        title3 "SINGLE COLLISION, PASSENGER COMPARTMENT";

*----------------------------------------------------
      This section uses the data set, "auto",
      to determine deformation characteristics.
It includes single vehicle, passenger vehicle,
side impact, fixed object collisions.
---------------------------------------------------;

     proc freq data=auto;
       format MAGINTRU magfmt. MAIS ms2fmt.;
       tables MAGINTRU*MAIS;
       where (VEHSEQ1=1) and (VEHSEQ2<1) and (OBJCONT2<0) and (near=2);
       title1 "MAGNITUDE OF INTRUSION BY MAIS (RAW)";
       title2 "SINGLE VEH, PASSENGER VEH., SIDE, FIXED OBJECT";
       title3 "SINGLE COLLISION, FAR-SIDE";

     proc freq data=auto;
       format MAGINTRU magfmt. MAIS ms2fmt.;
       tables MAGINTRU*MAIS;
       where (VEHSEQ1=1) and (VEHSEQ2<1) and (OBJCONT2<0) and (near=1);
       title1 "MAGNITUDE OF INTRUSION BY MAIS (RAW)";
       title2 "SINGLE VEH, PASSENGER VEH., SIDE, FIXED OBJECT";
       title3 "SINGLE COLLISION, NEAR-SIDE";

     proc freq data=auto;
       format MAGINTRU magfmt. MAIS ms2fmt.;
       tables MAGINTRU*MAIS;
       where (VEHSEQ1=1) and (VEHSEQ2<1) and (OBJCONT2<0);
       title1 "MAGNITUDE OF INTRUSION BY MAIS (RAW)";
       title2 "SINGLE VEH, PASSENGER VEH., SIDE, FIXED OBJECT";
       title3 "SINGLE COLLISION";
```

```
    proc freq data=auto;
      format MAGINTRU magfmt.;
      tables MAGINTRU*SHL1;
      where (3<MAIS<7) and (VEHSEQ1=1) and (VEHSEQ2<1) and (OBJCONT2<0) and (near=2)
      title1 "MAGNITUDE OF INTRUSION BY LOCATION OF IMPACT (RAW)";
      title2 "S.V., P.V., SIDE, FIXED OBJECT";
      title3 "MAIS >3, SINGLE EVENT, FAR-SIDE";

    proc freq data=auto;
      format MAGINTRU magfmt.;
      tables MAGINTRU*SHL1;
      where (3<MAIS<7) and (VEHSEQ1=1) and (VEHSEQ2<1) and (OBJCONT2<0) and (near=1)
      title1 "MAGNITUDE OF INTRUSION BY LOCATION OF IMPACT (RAW)";
      title2 "S.V., P.V., SIDE, FIXED OBJECT";
      title3 "MAIS >3, SINGLE EVENT, NEAR-SIDE";

    proc freq data=auto;
      format MAGINTRU magfmt.;
      tables MAGINTRU*SHL1;
      where (3<MAIS<7) and (VEHSEQ1=1) and (VEHSEQ2<1) and (OBJCONT2<0);
      title1 "MAGNITUDE OF INTRUSION BY LOCATION OF IMPACT (RAW)";
      title2 "S.V., P.V., SIDE, FIXED OBJECT";
      title3 "MAIS >3, SINGLE EVENT";

   proc freq data=auto;
      format crush crfmt. MAIS ms2fmt.;
      tables crush*MAIS;
      where (VEHSEQ1=1) and (VEHSEQ2<1) and (OBJCONT2<0);
      title1 "CRUSH VS MAIS (RAW)";
      title2 "SINGLE VEH, PASSENGER VEH, SIDE, FIXED OBJECT";
      title3 "SINGLE COLLISION";

run;
```

APPENDIX B
UNEXTRAPOLATED NASS DATA TABLES

Table 37. Occupant involvement by type of vehicle in single-vehicle, side-impact fixed-object collisions.

Vehicle	**1980-85 FARS**		**1982-85 NASS**	
Type	Frequency	Percent	Frequency	Percent
Passenger	1,647	79	2,240	78
Utility	262	13	328	11
Motorcycle	151	7	138	5
Truck	21	1	173	6
Bus	5	0	6	0
Other	10	1	1	0
Total	2,096	100	2,886	100

Table 38. Occupant involvements by fixed objects struck in single-passenger vehicle, side-impact, fixed-object accidents.

Object Struck	**1980-85 FARS**		**1982-85 NASS**	
	Frequency	Percent	Frequency	Percent
NARROW				
Tree	785	48	607	27
Utility Pole	434	26	522	23
Light Support	45	3	118	5
Other Post/Pole	39	2	112	5
Sign Support	11	1	52	3
Mail Box	–[1]	–[1]	18	1
Delineator Post	–[1]	–[1]	6	0
SUBTOTAL	1314	80	1,435	64
BROAD				
Guardrail	70	4	143	6
Bridge Pier/Abutment	44	3	23	1
Bridge Parapet	24	1	17	1
Wall	18	1	27	1
Fence	15	1	59	3
Bridge Rail	11	1	28	1
Concrete Barrier	4	0	21	1
Impact Attenuator	1	0	5	0
Other Long. Barrier	2	0	24	1
SUBTOTAL	189	11	347	15
OTHER				
Culvert	30	2	16	1
Other Fixed Object	30	2	86	4
Building	25	2	18	1
Embankment, Unknown	21	1	–[1]	–[1]
nn Embankment, Earth	13	1	101	5
Ditch	15	1	119	5
Embankment, Rock	6	0	20	1
Curb	2	0	98	4
Fire Hydrant	1	0	–[1]	–[1]
Shrubbery	1	0	–[1]	–[1]
SUBTOTAL	144	9	458	21
TOTALS	1,647	100	2,240	100

---

[1] Object was not in the data set.

Table 39. Occupant involvements by seating positions in relation to impact point.

Location of Impact	1980-85 FARS Frequency	1980-85 FARS Percent	1982-85 NASS Frequency	1982-85 NASS Percent
Near Side	974	59	1,055	47
Far Side	579	35	1,071	48
Other	94	6	114	5
Total	1,647	100	2,240	100

Table 40. Occupant involvement by passenger vehicle weights.

Vehicle Weight(kg)	1980-85 FARS Frequency	1980-85 FARS Percent	1982-85 NASS Frequency	1982-85 NASS Percent
Under720	64	0.7	38	2
810	339	4	38	2
910	525	6	125	6
1000	393	4	195	9
1090	735	8	132	6
1180	854	10	180	8
1270	708	8	144	6
1360	784	9	155	7
1450	1,074	12	191	8
1540	815	9	237	11
1630	724	8	224	10
1720	501	6	177	8
1810	494	6	149	7
1900	396	5	93	4
1990	139	2	85	4
2080	114	1	30	1
2170	41	1	27	1
2260	56	1	11	0
2360	4	0	6	0
Over 2360	9	0	3	0
Total	8,855	100	2,240	100
Missing	1,028		0	

Table 41. Occupant involvement by roadway type.

Roadway	**1980-85 FARS**		**1982-85 NASS**	
Type	Frequency	Percent	Frequency	Percent
Interstate	84	6	180	8
U.S. Highway	152	11	236	11
State Highway	428	30	584	26
County Road	370	26	588	26
Local Road	333	24	642	29
Other	50	3	9	0
Total	1,417	100	2,239	100
Missing			1	

Table 42. Occupant involvement by Federal aid.

Roadway	**1980-85 FARS**		**1982-85 NASS**	
Type	Frequency	Percent	Frequency	Percent
Federal Aid System				
Interstate	65	6	180	8
Other Primary Federal Aid	256	24	405	18
Federal Aid Secondary	205	19	341	15
Federal Aid Urban Arterial	158	15	342	15
Federal Aid Urban Collector	61	5	297	13
Total Federal Aid	745	69	1,565	70
Nonfederal Aid System				
Nonfed Aid Urban Arterial	20	2	9	0
Nonfed Aid Urban Collector	83	8	159	7
Nonfed Aid Local Collector	240	22	506	23
Total Nonfederal	343	32	674	30
Total	1,642	100	2,239	100
Missing			1	

Table 43. Occupant involvement by roadway alignment.

Roadway Alignment	**1980-85 FARS** Frequency	Percent	**1982-85 NASS** Frequency	Percent
Straight	845	51	1,162	56
Curve	799	49	925	44
TOTALS	1647	100	2,087	100
Missing			153	

Table 44. Occupant involvement by surface condition.

Surface Condition	**1980-85 FARS** Frequency	Percent	**1982-85 NASS** Frequency	Percent
Dry	1,238	75	1,285	58
Wet	305	19	592	27
Snow/Slush	40	2	116	5
Ice	51	3	202	9
Other	14	1	8	1
Totals	1647	100	2,203	100
Missing			37	

Table 45. Occupant involvement by injury in side-impact collisions.

Type of Injury	Frequency	Percent
No Injury(0)	980	45
Possible Injury(C)	276	13
NonIncapaciting Injury(B)	430	20
Incapacitating Injury(A)	421	19
Killed(K)	59	3
Unknown	21	0
Total	2,187	100
Missing	53	

Table 46. Occupant involvement in guardrail collisions.

Guardrail Type	Police Reported Injury						Total	
	No or Minor Injury(0+C+B)		Incapacitating Injury(A)		Killed(K)			
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Non-Median	88	91	9	9	0	0	97	66
Median	20	95	1	5	0	0	21	15
End(Non-Median)	14	82	2	12	1	6	17	12
Bridge Transition	4	80	0	0	1	20	5	3
End(Median)	1	17	4	66	1	17	6	4
Totals	127	100	16	100	3	100	146	100

Table 47. Occupant involvement by location of impact on vehicle.

Location of Impact	**Nonincap. (0+B+C)**		**Incap. A+K**		**Unknown**		**Total**	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
U	497	85	87	15	2	0	586	27
F	302	84	53	15	3	1	358	16
D	225	78	59	21	3	1	287	13
P	209	64	116	35	4	1	329	15
Z	153	73	50	24	6	3	209	10
Y	167	65	88	35	0	0	255	12
B	133	82	27	16	3	2	163	7
Total	1,686	77	480	22	21	1	2,187	100
Missing							53	

Table 48. Occupant involvement by injury in passenger compartment collisions.

Type of Injury	Frequency	Percent
No Injury (0)	92	28
Possible Injury (C)	38	12
Non-Incapacitating Injury (B)	79	24
Incapacitating Injury (A)	94	29
Killed (K)	22	7
Unknown	4	0
Total	329	100

Table 49. Occupant involvement by body region injured.

Body Region	**All Injuries**		**AIS Over 3**	
	Freq.	Percent	Freq.	Percent
Head-Skull	112	23	10	50
Chest	25	5	6	30
Whole Body	5	1	1	5
Abdomen	11	2	3	15
Face	104	22	-	-
Neck-Cerv.Spine	35	7	-	-
Injured, Unknown	14	9	-	-
Knee	20	4	-	-
Wrist	21	4	-	-
Shoulder	19	4	-	-
Back-Thorac.Spine	17	4	-	-
Ankle-Foot	15	3	-	-
Thigh	12	3	-	-
Unknown	6	1	-	-
Upper Limbs	4	1	-	-
Elbow	9	2	-	-
Pelvic-Hip	8	2	-	-
Upper Arm	6	1	-	-
Lower Leg	7	2	-	-
Forearm	2	0	-	-
Total	479	100	20	100

Table 50. Occupant body region injured versus type of object struck – all injury severities.

Body Region	**Type of Object Struck**						**Total**	
	Narrow		**Broad**		**Other**			
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Face	75	72	10	10	19	18	104	100
Head-Skull	90	80	11	10	11	10	112	100
Neck-Cerv.Spine	21	60	6	17	8	23	35	100
Chest	23	92	0	0	2	8	25	100
Abdomen	10	91	0	0	1	9	11	100
Whole Body	3	60	1	20	1	20	5	100

Table 51. Source of injury to involved occupants.

Injury Source	**All Injuries**		**MAIS over3**	
	Freq.	Percent	Freq.	Percent
Unknown Source	199	42	6	30
Unknown Object in Environment	2	0	2	10
Side Hardware	15	3	1	5
Window Glass/Frame	18	4	1	5
A Pillar	14	3	3	15
Non-Contact Injury	37	8	1	5
Steering Assembly	27	6	1	5
Side Interior	30	6	2	10
Roof Side Rails	8	2	1	5
Floor Trans.Lever	3	0	1	5
Seat Back Supp.	13	3	1	5
Windshield	41	9	-	-
Instrument Panel	33	7	-	-
Mirror	8	2	-	-
Roof/Conv.Top	4	1	-	-
Belt Restraint System	3	1	-	-
Other	18	3	-	-
Total	473	100	20	100
Missing	6		0	

Table 52. Age of occupants.

Age	Freq.	Percent	Cum. Percent
0-15	169	8	8
16-19	659	30	38
20-24	568	26	64
25-34	434	20	84
35-44	157	7	91
45-54	79	4	95
55-64	56	3	98
Over 64	47	2	100
Missing	71		

Table 53. Occupant involvement by time of accident.

Time	Frequency	Percent	Cum. Percent
8pm-12am	551	26	26
12-4 am	588	26	52
4-8am	245	11	63
8am-12pm	222	10	73
12-4 pm	266	12	85
4-8 pm	330	15	100
Missing	38		

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