UM-HSRI-SA-75-2

Rear-Impacted-Vehicle Collisions: Frequencies and Casualty Patterns

Technical Report

July 1975

by

James O'Day
Lyle D. Filkins
Charles P. Compton
Thomas E. Lawson

Distributed to

Motor Vehicle Manufacturers Association

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48105

Technical Report Documentation Page

1. Report No. UM-HSRI-SA-75-2	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Rear-Impacted Vehicle Collisions: Frequencies and Casualty Patterns	5. Report Date July 1975
	6. Performing Organization Code
7. Author(s) James O'Day, Lyle D. Filkins, Charles P. Compton, Thomas E. Lawson	8. Performing Organization Report No. UM-HSRI-SA-75-2
9. Performing Organization Name and Address Highway Safety Research Institute The University of Michigan Ann Arbor, Michigan 48105	10. Work Unit No. 329490
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Motor Vehicle Manufacturers Association 320 New Center Building Detroit, Michigan 48202	13. Type of Report and Period Covered Final Report 11/74 - 7/75
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The purposes of the study were to determine whether accident data at HSRI support the strengthening of federal standards 202 (Head Restraints) and 207 (Anchorage of Seats). Rear-end crashes and injuries to occupants of rear-damaged vehicles were emphasized. Police reports from Texas (1973) and multidisciplinary accident investigations were the principal data sources.

Rear-end collisions were found to be the most frequent but the least serious of all two-vehicle collisions. The National Safety Council estimate of their annual frequency is about twice that obtained by extrapolating Texas data nationwide. The number of reducible neck whiplash injuries occurring annually is about 172,000, about one-fifth that cited by Federal officials. Seat separation and injury severity are correlated with crash severity, but the data do not permit determination of whether these factors are causally related; seatback deflection was also associated with impact severity but showed no significant relationship to injury severity in the CPIR data. Weaknesses in available data are discussed, and recommendations for improving future data collection and analysis are included.

17. Key Words Rear-end collisions; rear-damaged vehicles; injury patterns; FMVSS 202,207; seating system components	18. Distribution Statement Unlimited

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

Reproduction of completed page authorized

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES
IN APPENDICES

SUMMARY

METHODOLOGY, CONCLUSIONS, RECOMMENDATIONS

METHODOLOGY

Collision configurations and injuries were studied in accident data files maintained at HSRI, with particular emphasis on rear-end crashes and injuries to occupants of cars damaged in the rear. To place rear-end collisions and rear-damaged cars in perspective, some descriptive statistics were derived for the general accident population.

Data files addressed in this study are of two general types--(1) police-reported data, and (2) in-depth (Multidisciplinary accident investigation) data. The former represent essentially a census of accidents reported to police in each of the several areas studied. The latter represent a selection of (generally) more severe crashes and a selection process that has introduced some known and unknown biases into the data.

While the police-reported accidents lack detail, they permit a look at both the relative frequency and severity of rear-end crashes. The in-depth data contain such elements as seat separation, injury-type, and extent of vehicle damage, and this permits some analysis of the interrelationship of such factors.

Some limitations of the data must be kept in mind. Crash-severity measures (e.g., the Collision Deformation Classification) are not precise enough to permit complete isolation of such factors as seat failure as an injury-producing mechanism. But if an effect is strong enough, the data do provide useful results. The accident data can give considerable insight into the existence of a problem, but they cannot provide design parameters for the solution of the problem. We have noted in the text those areas deserving further design and experimental effort.

CONCLUSIONS

1. Annual Frequency of Rear-Impact Crashes in U.S. Rear-impacted vehicles constitute approximately 20% of all damaged vehicles in accidents reported by police agencies--an estimated 2,180,000 vehicles annually.

2. Severity of Rear-Impact Collisions. While rear impacts are frequent, relatively few of them are severe, injury-producing crashes. In 91% of such impacts, police reports indicate that occupants of the vehicle suffered no injuries. Police-reported minor injuries are incurred in 6.8% of such impacts, moderate injuries in 1.7%, severe injuries in 0.4%, and fatal injuries in 0.06% of those impacts (the latter accounting for approximately 1,200 fatalities annually in the U.S.).

3. Annual Frequency of Whiplash Injuries. Whiplash neck injuries are poorly defined and understood generally. They tend to be minor and frequently are recognized a day or more after the accident, and thus they are highly under-reported among police data. Using a broad injury definition, the number of whiplash injuries occurring nationwide in rear-impacted vehicles (estimated from incidence and occupancy data in research studies) is about $1\frac{1}{4}$ million annually. Federal estimates of the number of these that might be reducible by head restraints appear highly optimistic, in that they are unsupported by findings obtainable from currently available accident data.

4. Effect of Seat Belt Use on Rear-Impact Injuries. Analyses of available data* show no significant difference in the frequency or severity of injuries to seat-belted and non-seat-belted occupants of rear-impacted vehicles.

---

*Only the current Restraint Systems Effectiveness Study file provides data which have been obtained by proper sampling techniques and which contain adequate information on belt usage and occupant injury.

5. Effect of Head Restraints on Neck Injuries. Analyses of available in-depth data* do not show significant relationships between "whiplash" injuries and the presence or absence of head restraints. This may result from field teams having selected generally more severe accidents for investigation and inclusion in the file. The more likely explanation is that head restraints reduce neck injuries so little that the reduction is not detectable with the given sample sizes.

6. Effect of Seat Separation on Injuries. Available data show* , expectably, that the more severe a crash, the more likely it is that seats will separate and occupant injuries will be severe. However, the data lack the precision necessary to confirm a causal relationship between seat separation and frequency or severity of injuries in rear impacts.

7. Effect of Seatback Deflection on Injuries. Available data show* , expectably, that the more severe a crash, the more likely it is that seatback deflection will occur. However, the data again lack the precision necessary to establish any causal relationship between seatback deflection and frequency or severity of injuries.

8. Methodological Considerations. The best current means of assessing the role of head restraints and other seating system components are experimental crash tests and carefully controlled field studies directed to specific research questions.

RECOMMENDATIONS

We have attempted to present here a picture of the incidence of rear-impacted vehicles, of injuries to occupants in rear impacts, and of interactions with certain characteristics of the seating systems, such as head restraints and/or separation from the mounting. Limitations of the existing data

---

*Only the Collision Performance and Injury Report file contains variables which can be used for studying these problems.

become most apparent when one addresses such specific problems, and there are several directions which are appropriate to strengthen the data for such analyses in the future.

The crash-severity measures currently available in the in-depth files are not sufficient to resolve the dynamic conditions of the crash well enough to judge the injury-producing effects of seat strength for rear impacts. The highway safety community sorely needs a definition of crash severity precise enough so that it can be adequately applied and effectively utilized in data analyses. The work of Carlson (1), Campbell (2), and others have been attempts in this direction, but there is a real need for implementing a workable system now. This should become a separate research project with adequate funding for development of the measure(s) as well as for incorporation of the measure in the file for existing cases.

Whiplash (i.e., dynamic non-contact) injuries to parts of the body other than just the neck, and in collision configurations other than rear-impact, should be considered in subsequent modifications of seating systems.

In the CPIR file "whiplash" is included as part of a catchall contact code that makes analysis for only whiplash injuries difficult. Only 24.4% of "whiplash"-associated neck injuries occurred in rear-damaged vehicles, and "whiplash"-associated injuries occurred in all body regions. We have only lightly reviewed these phenomena here, but they should be looked at further.

The identification and recording of whiplash injuries by MDAI field investigations should be refined. The present injury scales (both the AIS and the police KABC scale) do not provide for adequate description of such injuries. Although the latent effects of other injuries (such as broken arm) are reasonably well known, complaints of whiplash injuries are so common that such injuries need to be much more carefully defined in accident-investigation forms and injury codes.

1.0 INTRODUCTION

Rear-end collisions continue to be the most common of the four two-vehicle collision configurations reported by the National Safety Council (NSC), with some 4,300,000--about 1/3 of all two-vehicle collisions--estimated for 1973 (3). O'Neill *et al* speculated that if their insurance company claims data were typical and applicable to the U.S. generally, there might be as many as 1,000,000 drivers alone experiencing whiplash injuries from such collisions, quite apart from other occupants and other types of injuries (4). The recent report of the Comptroller General quotes NHTSA officials as estimating that "properly adjusted head restraints could prevent approximately 931,000 whiplash injuries a year." (5). These stated frequencies of rear-end collisions, resulting injuries, and potential for injury reduction are all large. Whether they are accurate or not, it is clear that these topics merit ongoing attention, particularly in view of States' observation, following an extensive review of the literature, that the incidence of injury occurring in rear-end accidents has never been conclusively determined (6).

Additional impetus is given to an investigation of these topics by the National Highway Traffic Safety Administration's proposed revisions of Federal Motor Vehicle Safety Standards 202 and 207. Standard 202 (Head Restraints) became effective January 1, 1969 and Standard 207 (Anchorage of Seats) became effective January 1, 1968 for passenger cars. These standards have now been in effect over 6 years, and determination of their effectiveness is appropriate.

The purposes here, therefore, are to present pertinent accident data which have been collected since the standards became effective and to report some of the analyses which have been conducted with these data. The analyses have attempted to determine whether current empirical data lend support to strengthening and extending the two standards dealing with seating systems. The study has focused on rear-end collisions and on vehicles which have incurred rear-end damage, because beneficial effects deriving from proper seating-system design and construction should be most readily apparent in these cases. Other collision configurations have been included, however, both to provide a context in which rear-end collisions should be viewed and because seating systems may influence injury patterns in other accident configurations.

An important limitation in the scope of the study is that the data were obtained from police-investigated accident investigations and from multidisciplinary accident investigation teams. Data from both sources, particularly the police agencies, are generally gathered within hours of the occurrence of an accident. McLean, in North Carolina (7), and States in Rochester, New York (6), have shown that symptoms of neck injuries frequently do not appear for several hours, or even a few days, following an accident. Therefore the data sources used in this study are highly likely to have under-reported the frequency of neck injuries. It will be seen subsequently that this phenomenon has been accounted for in extrapolating data from the State of Texas to a nationwide frequency, but the reader is cautioned that elsewhere in the report the reported frequencies of injuries have been used "as is" without a correction.

Section 2 - Rear-Damaged Vehicles in Perspective--provides general information about rear-end collisions and rear-damaged vehicles from an overview perspective. Section 3 focuses on seat separation and injury patterns in various collision configurations and examines the interactions among these factors. Section 4 focuses on rear-impacted vehicles and on casualty patterns occurring among such vehicles, and examines specifically seating system components and associated injuries. Several appendices contain both general contextual information and presentations of detailed data on which the text is based.

2.0 REAR-DAMAGE VEHICLES IN PERSPECTIVE

2.1 Introduction

This section provides an overall structure in which rear-damaged vehicles should be considered. Similarities and differences between rear-damaged vehicles and vehicles in rear-end collisions are noted, and National Safety Council estimates for the nationwide frequency of rear-end collisions are reviewed. Injury frequencies and severities to occupants of rear-damaged vehicles are given, and the damage severities and vehicle types associated with rear-damage vehicles are presented. Also included are data about injuries to occupants of vehicles incurring damage in more than one location. Seat-belt performance in rear-damaged vehicles is included, and the section concludes with nationwide estimates of both the frequency of rear-damaged vehicles and the frequency of whiplash injuries in such vehicles.

2.2 Frequencies and Percentages of Rear-End Collisions and Fatal Rear-End Collisions

Each year the National Safety Council estimates the nationwide frequency of fatal and total accidents. For 1973, Figure 1 shows the percentage of all collisions of given configurations and the percentage of fatal collisions for the same configurations, and Table F-1 (Appendix F) details the frequency data. Note that rear-end collisions comprise 25.9% of all collisions but only 4.8% of all fatal collisions. Further, two-vehicle, rear-end collisions comprise 33.1% of all two-vehicle collisions but only 11.9% of fatal, two-vehicle collisions.

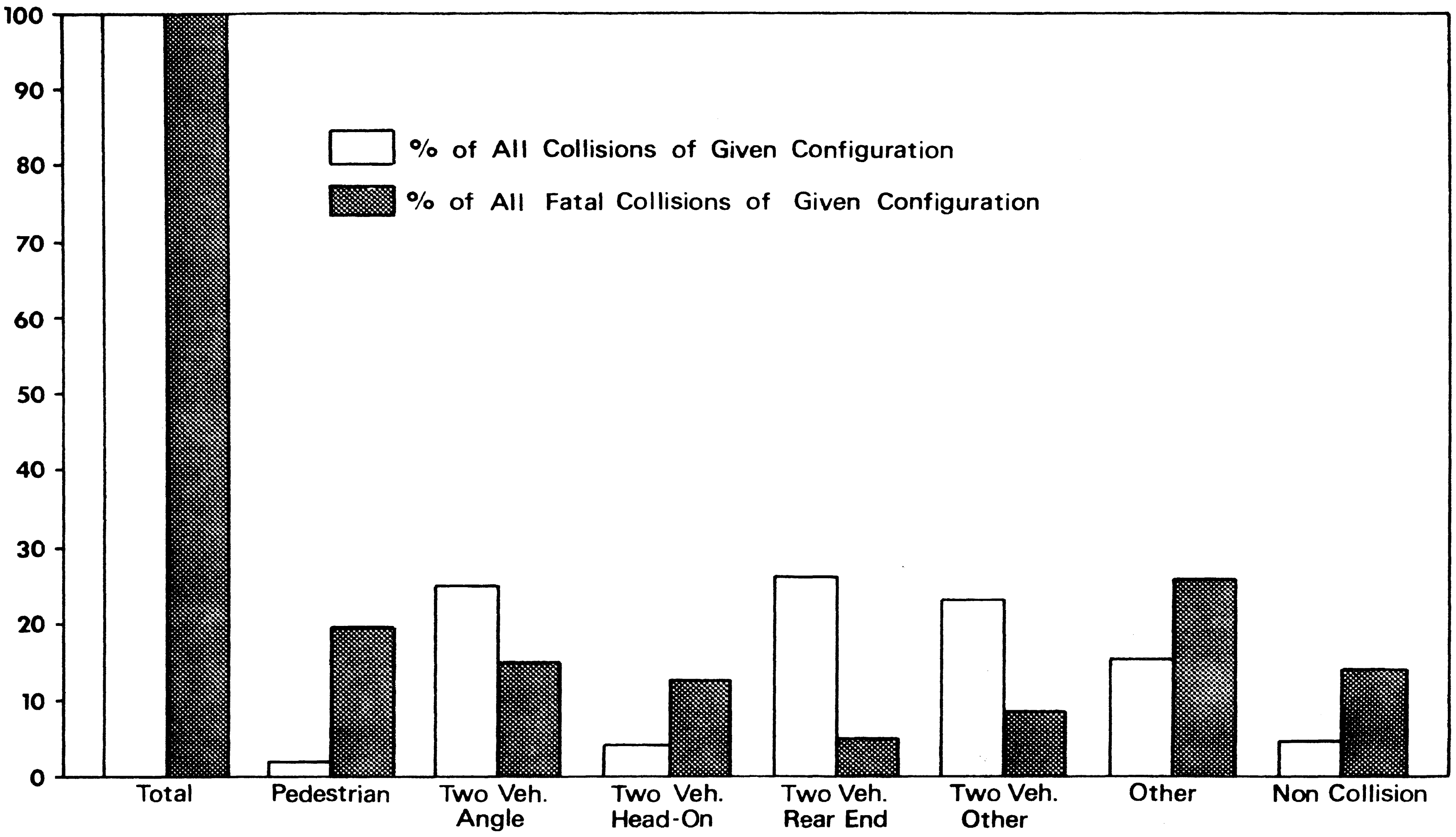
The distribution of vehicles involved in fatal accidents and fatalities in those vehicles in Texas during 1973 is shown in Table F-2, Appendix F. Of the 5,108 vehicles in fatal accidents, 414 (8.1%) were involved in rear-end collisions. Of the 3670 total fatalities, 229 (6.2%) occurred in rear-end accidents.

2.3 Rear-End Collisions and Rear-Damaged Vehicles

It might be expected that about half the vehicles involved in rear-end collisions would exhibit rear-end damage. Table F-3

Figure 1

National Safety Council Estimates: Percent of Fatal and Total Accidents for Given Collision Configurations, 1973



in Appendix F, prepared from the Texas 5% Sample File of 1973 accidents, reveals that this is not true, however.[*] The table, a bivariate distribution of vehicles by collision configuration and damage area,[**] shows that only 36.2% (3967) of all vehicles for which a damage determination was made in rear-end collisions suffered rear-end damage. By way of comparison the percentages of other general damage areas follow: front - 40.4%, side - 23.3%, and top - 0.1%.

On the other hand, rear-end damage does occur in non-rear-end collision configurations. Of the 5,430 vehicles in the file showing rear-end damage, 73.1% (3967) were in rear-end collisions. Head-on collisions accounted for 4.5%; side-swipes accounted for 3.2%; angle collisions combined to account for 7.8%; single-vehicle collisions accounted for 6.9%; and the other 4.6% occurred in other unspecified configurations.

To assist in choosing a set of vehicles for subsequent analysis, passenger cars and pickup trucks from the Collision Performance and Injury Report (CPIR)[***] File were also examined. Agreement between the impact areas and the impact vectors was generally high. Specifically, it was found that 98.7% of all rear-damaged vehicles have 05-, 06-, or 07-o'clock impact vectors, and that 86.7% of vehicles with these three impact vectors exhibited rear-end damage. It was concluded, therefore, that the more appropriate vehicles for subsequent analysis were those with rear-end damage, irrespective of the pre-crash collision maneuvers. Furthermore, rear-impacted vehicles subject their front-seat occupants to forces which bring the head restraints and seatbacks into their restraining role.

---

[*] i.e., the police report that one vehicle struck another in the rear may actually involve principal reported damage to the side of the struck car.

[**] Texas police use the TAD method of reporting damage location and severity. See (8) for more detail.

[***] The CPIR file is described in Appendix A.

2.4 Vehicle Damage Area and Injury Severity

Five mass data files, covering four different jurisdictions, were used to determine the distribution of injury casualties and fatalities by damage area: (1) Texas (1973) Fatal Vehicle File; (2) Texas (1973) 5% Sample Vehicle File; (3) Washtenaw County, Michigan (1970-1973) Vehicle File; (4) Oakland County, Michigan (1973) Vehicle File; and (5) Denver County (1973) Vehicle File. The results are shown in Tables 1 through 4.

Table 1 displays the results for the 1973 Texas data, revealing that 17.0% of the damaged vehicles sustained rear-end damage. Of persons sustaining "C" injuries, 23.2% were occupants of rear-damaged vehicles; it can be seen that this is the only cell in the rear-damage column which is over-represented with respect to the percentage of rear-damaged vehicles. As injury severity increases, the percentage of injured persons occupying rear-damaged vehicles drops sharply. The "A" injury and fatality cells are under-represented by factors of 8.5 (17.0%/2.0%) and 6.3 (17.0%/2.7%).

The under-representation of fatalities and injured occupants in rear-impacts found in the Texas data is also found in Washtenaw County (Table 2). Here 23.7% of the vehicles are rear-impacted, but the occupants of these vehicles account for only 5.1% of the fatalities and 18.0% of the injuries. Similar results also hold for Oakland County and for Denver County (Tables 3 and 4). The data from Denver are probably less reliable than those from the other reporting areas, because it is not possible to assign an area of worst damage or primary impact for 30.7% of the vehicles.

Figures 2 and 3 display these results graphically for the 1973 Texas data. Figure 2 shows that rear-damaged vehicles represent 13.9% of all traffic units involved in accidents. Figure 3 demonstrates the relative percentages of vehicles damaged in different areas for those vehicles where a determination of damage area was made. The length of the arrow represents the number of vehicles incurring damage to an area. The shaded areas represent injuries. It can be seen that rear-damaged vehicles

Table 1

Percentage Distribution of Damaged Vehicles and Injured Occupants by Damage Area and Injury Severity: Texas (1973)

	Damage Area				
	Back	Front	Side	Top	Total
Damaged Vehicles*	17.0%	41.6%	39.8%	1.5%	100% (31,886)
"C" Injury Occupants*	23.2%	38.6%	34.6%	3.6%	100% (2079)
"B" Injury Occupants*	5.1%	54.7%	32.2%	8.1%	100% (2426)
"A" Injury Occupants*	2.0%	61.0%	28.5%	8.5%	100% (981)
Fatalities**	2.7%	45.0%	35.4%	17.0%	100% (2763)

*Data source: Texas (1973) 5% Sample Vehicle File

**Data source: Texas (1973) Fatal Vehicle File

Table 2

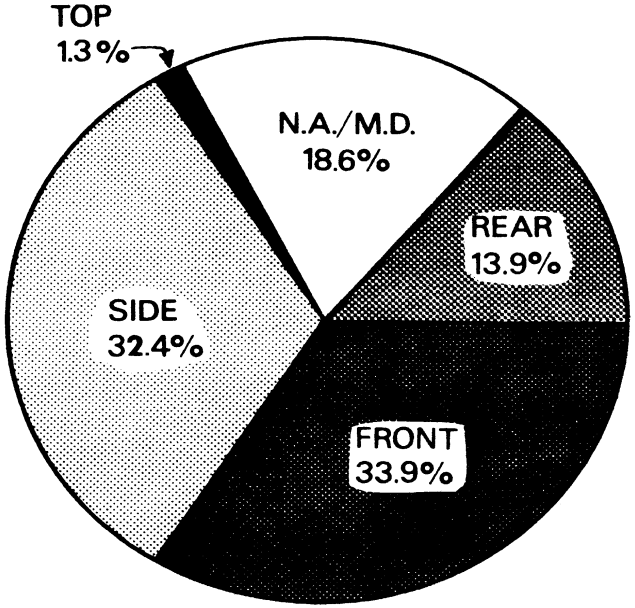
Percentage Distribution of Vehicles and Injured Occupants by Damage Area: Washtenaw County (1970-1973)

	Damage Area					
% of Total	Rear	Front	Sides	Top	M.D. & Other	Total
Damaged Vehicles	23.7%	55.8%	14.0%	3.4%	3.1%	100% (52,244)
Injured Occupants	18.0%	55.6%	13.7%	9.9%	2.8%	100% (14,236)
Fatalities	5.1%	48.5%	19.6%	25.1%	1.7%	100% (235)

*"A", "B", and "C" injuries.

Figure 2

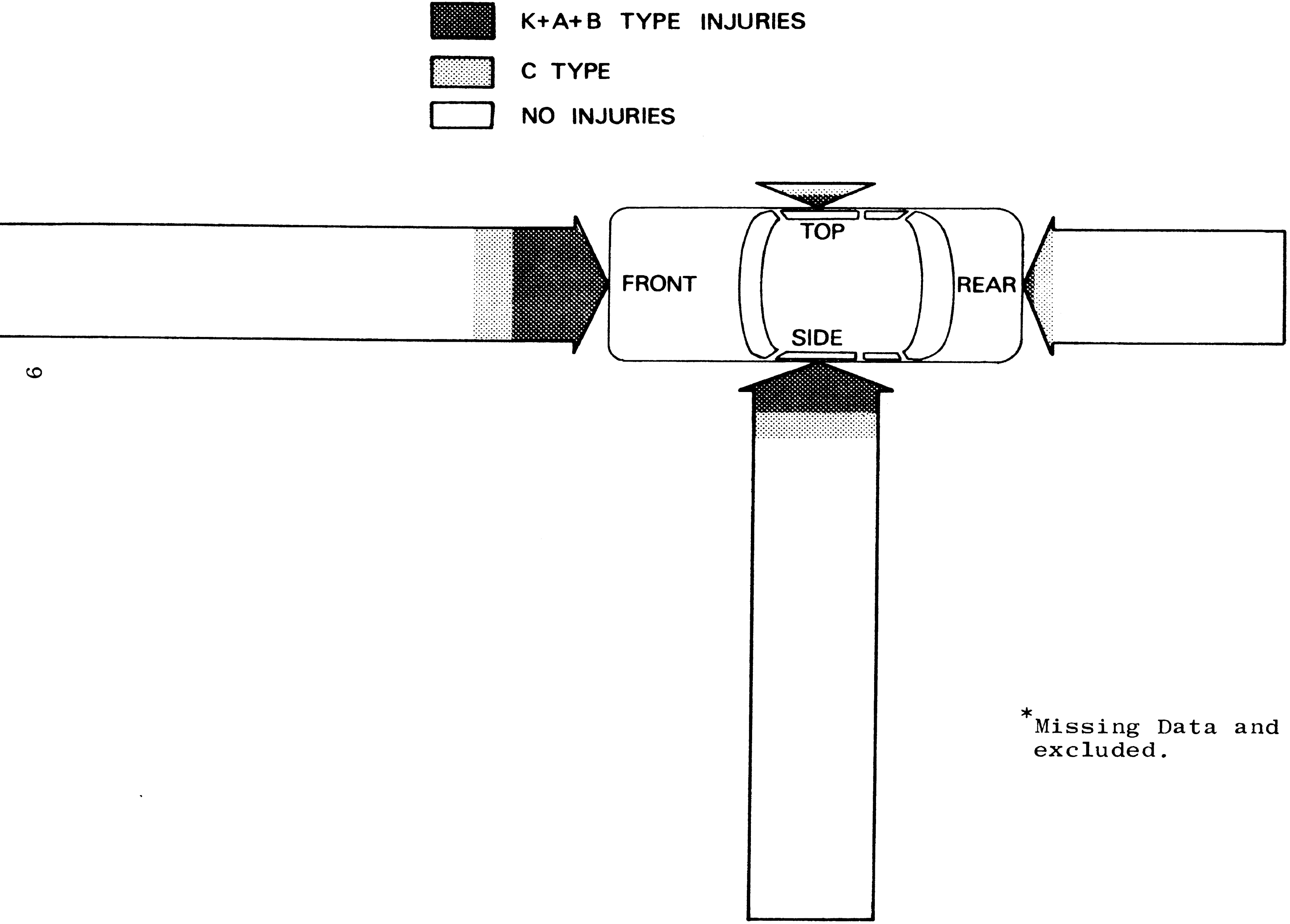
Representation of All Traffic Units[*] by Damage Area in the Texas 5% Sample File (1973)



[*] Traffic Units include pedestrians, motorcycles, and others for which damage area cannot be defined. These are reported as "not applicable" (N.A.) and are included with the "missing data" (M.D.).

Figure 3

Percentage of Vehicles by Damage Area and the Percentage of Injury Severities for Each Damage Area in the Texas 5% Sample (1973)*



*Missing Data and Not Applicable excluded.

Table 3

Percentage Distribution of Vehicles and Worst Injury Sustained by Damage Area: Oakland County (1973)

	Damage Area					
	Rear	Front	Sides	Top	M.D. & Other	Total
Damaged vehicles	25.8%	58.0%	12.4%	1.1%	2.7%	100% (57,133)
A&B Injuries	7.3%	70.6%	14.6%	4.5%	3.0%	100% (4812)
C Injuries	35.4%	45.7%	11.4%	1.3%	6.3%	100% (7147)
Fatalities	5.4%	54.1%	24.3%	16.2%	0.0%	100% (111)

Table 4

Percentage Distribution of Vehicles and Worst Injury Sustained by Damage Area: Denver County (1973)

	Damage Area					
	Rear	Front	Sides	Top	M.D. & Other	Total
Damaged vehicles	16.7%	32.9%	19.5%	0.2%	30.7%	100% (60,323)
A&B Injuries	4.8%	34.7%	12.0%	1.2%	47.3%	100% (2847)
C Injuries	27.8%	23.8%	14.0%	0.6%	33.8%	100% (2283)
Fatalities	0.0%	6.9%	13.8%	3.4%	75.9%	100% (29)

comprise relatively less of the accident and injury problem than do either front- or side-damaged vehicles. The under-representation of severe injuries in rear-damaged vehicles, relative to other impact areas, is also readily apparent.

While rear-impacted vehicles are not as important producers of fatalities and severe injuries as are vehicles damaged elsewhere, they do represent a large proportion of the vehicles in crashes. The percent of vehicles in Texas that were rear-impacted is 17.0%. This number is supported by the figures from Washtenaw and Oakland Counties--23.7% and 25.8%. These reporting areas are more densely populated than the State of Texas, and Oakland is somewhat more urban than Washtenaw. Since the National Safety Council estimates that 79% of all rear-end crashes occur in urban areas, these reporting areas should have a larger percentage of rear-impacts than a more rural environment. Removing the 30.7% of the vehicles with unclassified impacts from the Denver data leaves 24.1% of the vehicles in the rear-impact category, consistent with Washtenaw and Oakland Counties.

The most important finding from these tables is the under-representation of fatalities and severe injuries in rear-impacted vehicles. This finding is unanimous from all four reporting areas, and the amount of under-representation is large.

2.5 Damage Severity and Injury Severity

Severely injured occupants are under-represented among rear-impacted vehicles, compared to those in vehicles with other damage areas. A further inquiry into this pattern in terms of damage severity to the involved vehicles was undertaken.

Table 5 displays the percentage distribution of 1973 Texas vehicles by the location and severity components of the TAD (Traffic Accident Data) damage scale. The TAD-scale ratings are not directly comparable for different damage areas, but better measures of accident severity are not currently available in police data. Rear-impacted vehicles, 17.0% of the total, are both the only vehicles with an over-representation (24.0%) among those with least damage (TAD "0" and "1") and the only vehicles under-represented in each of the more severe damage categories.

The Denver data, with their three-level damage scale--minor, moderate, and severe--parallel the Texas data. Table 6 shows that rear-impacted vehicles are over-represented (30.6%) among those with minor damage compared to their percentage (24.2%) of all vehicles. Conversely, they are under-represented in the more severe categories. Side impacts peak with an over-representation among those with moderate damage; frontal impacts peak with an over-representation among the severely damaged.

A rough measure of vehicle damage severity for the Washtenaw and Oakland County data is whether the vehicle was driven or towed from the scene. The noteworthy features of these tables (7, 8) are the marked under-representation of rear-impacted vehicles among those towed from the scene and the marked over-representation of frontally-impacted vehicles in the same group.

All four mass accident data files show rear-impacted vehicles as a group to be less severely damaged than vehicles with other types of impacts. This holds across three states and three methods of measuring damage. The unanimity of these results suggests that the national picture is similar.

A natural assumption is that there is a strong correlation between lesser physical damage to the vehicle and fewer injuries to occupants in rear-impacted crashes. While the correlation exists, there is another factor. Table 9 indicates that in Texas a large proportion of the injuries in rear-impacted vehicles are occurring at a low TAD-scale rating. Not only are 45.8% of the injuries in rear-impacted vehicles occurring at a TAD of 2 or less (compared to 16.5% of the injuries in vehicles with other types of impacts), but rear-impacted vehicles account for 26.3%* of all injuries at a TAD of 2 or less and are only 17.0% (Table 5) of the vehicles.

---

*Derived from Table 9: $\frac{626 \times (24.1\% + 21.7\%)}{5486 \times (6.7\% + 13.2\%)} = 26.3\%$

Table 5

Percentage Distribution of Vehicles by Damage Area and Damage Severity Code: Texas (1973) 5% Sample Vehicle File

	Damage Area					
	Rear	Front	Sides	Top	Total	N
Total	17.0%	41.6%	39.8%	1.6%	100%	(31,886)
TAD Damage Severity						
0-1	24.0%	37.2%	38.7%	0.1%	100%	(13,481)
2	14.8%	40.7%	44.0%	0.5%	100%	(8,907)
3	10.5%	46.4%	41.0%	2.0%	100%	(5,962)
4-7	6.9%	52.9%	31.6%	8.6%	100%	(3,536)

Table 6

Percentage Distribution of Vehicles by Damage Area and Damage Severity: Denver County (1973)

	Damage Area				
	Rear	Front	Sides	Total	N
Total	24.2%	47.6%	28.2%	100%	(41,580)
Damage Severity					
Minor	30.6%	44.7%	24.7%	100%	(18,438)
Moderate	21.9%	45.5%	32.6%	100%	(14,856)
Severe	14.1%	57.9%	28.0%	100%	(8,286)

Missing data have been excluded from the Tables above.

Table 7

Percentage Distribution of Vehicles by Damage Area and Post-Crash Condition: Washtenaw County (1970-1973)

			Damage Area			
	Rear	Front	Sides	Top	Other	Total
Total	24.7%	57.6%	13.3%	1.9%	2.4%	100% (40,352)
Driven	30.8%	52.6%	14.2%	0.2%	2.2%	100% (25,432)*
Towed	11.0%	69.6%	11.2%	5.6%	2.7%	100% (12,671)*

* 2,249 vehicles with missing data have been excluded.

Table 8

Percentage Distribution of Vehicles by Damage Area and Post-Crash Condition: Oakland County (1973)

			Damage Area			
	Rear	Front	Sides	Top	Other	Total
Total	25.8%	58.0%	12.4%	1.1%	2.7%	100% (57,133)
Driven	31.7%	52.4%	12.9%	0.2%	2.7%	100% (41,378)*
Towed	10.2%	72.8%	11.1%	3.3%	2.6%	100% (15,617)*

* 138 vehicles missing data

Washtenaw County exhibits parallel results. From Table 10 it is seen that 61.0% of the injuries in rear-impacted vehicles are occurring in vehicles driven from the scene, a percentage much higher than for vehicles with other types of impacts. And rear-impacted vehicles account for 43.0%[**] of all the injuries in drivable vehicles, while they are only 24.7% (Table 7) of all vehicles.

In Table 3 rear-impacted vehicles--25.8% of all impacts--in Oakland County, Michigan were shown to account for 35.4% of the vehicles with a Worst Injury level of "C" on the K-A-B-C scale. Of the 2527 rear-impacted vehicles which make up this 35.4%, 2066 were driven from the scene (81.8%). Comparatively, of the 4620 vehicles with other types of impacts and a Worst Injury level of "C", only 1921 were driven from the scene (41.6%).

2.6 Crash and Injury Patterns by Vehicle Type

To examine further the patterns that appear among rear-impacted vehicles, the frequency and the severity of the involvements of various types of vehicles were determined.

2.6.1 Oakland County Data

Table 11 shows the distribution of vehicle types in Oakland County crashes in 1973. The variation in percentage between all vehicles, rear-damaged vehicles, and front-damaged vehicles is minor for all types of vehicles. However, all types of trucks in rear-end collisions are over-represented among those damaged in the front and are under-represented among those damaged in the rear with respect to their percentage among all crash-involved trucks. There are probably many factors, such as higher visibility of large trucks and perhaps a tendency of motorists to drive with greater headway between trucks and themselves, which contribute to this pattern.

[**] Derived from Table 10: $\frac{2027 \times 61.0\%}{10{,}679 \times 26.9\%} = 43.0\%$

Table 9

Percentage Distribution of Injured Occupants by Damage Area and Damage Severity Code: Texas (1973) 5% Sample Vehicle File

Damage Area	TAD Damage Scale 0-1	 2	 3	 4-7	Total
Rear	24.1%	21.7%	25.9%	28.3%	100% (626)
Other	4.4%	12.1%	25.4%	58.1%	100% (4860)
Total	6.7%	13.2%	25.4%	54.7%	100% (5486)

Table 10

Percentage Distribution of Injured Occupants by Rear/Front Damage and Post-Crash Condition: Washtenaw County (1970-1973)

	Post-Crash Condition				
Damage Area	Driven	Towed	M.D.	Total	
Rear	61.0%	34.4%	4.6%	100%	(2027)
Front	19.0%	78.2%	2.8%	100%	(8652)
Total	26.9%	69.9%	3.1%	100%	(10,679)

Table 11

Distribution of Crash-Involved Vehicles by Type of Vehicle and Rear/Front Damage Area: Oakland County (1973)

				Rear-End Collisions			
		All Crashes		Rear Damage		Front Damage	
	Type	N	%	N	%	N	%
	Full	30342	51.7	4097	53.8	3786	51.6
Cars	Inter.	11179	19.1	1488	19.5	1384	18.9
	Comp.	8052	13.7	1164	15.3	1039	14.2
	Sport	1345	2.3	226	3.0	165	2.3
	Jeep	149	0.3	14	0.2	18	0.2
Large Trucks	Carryall, Van	1737	3.0	42	0.6	53	0.7
	Pickup	3281	5.6	314	4.1	499	6.8
	Truck	1891	3.2	198	2.6	300	4.1
	Semi	685	1.2	69	0.9	87	1.2
		58,661	100.0	7612	100.0	7331	100.0

Table 12 shows the severity of casualties by vehicle type, among rear-damaged vehicles in Oakland County in 1973. Large trucks have the highest percentage of "No Injury" of all vehicle types. Of all rear-damaged vehicles, cars damaged in the rear have the lowest percentage of "No Injury" and the highest percentage of "C" injuries of all vehicle types. Jeeps, Carryall/Vans and Pickups form an intermediate group in "No Injury", but have a rate of "K,A,B" injuries comparable to cars.

2.6.2 Texas Data

Table 13 shows the distribution of vehicle types in Texas crashes (through use of the 5% Sample file) in 1973. Here too, the variations in percentage are minor. However, cars are over-represented and trucks of all kinds are under-represented among those damaged in the rear in rear-end crashes.[*] Among

---

[*] $X^2 = 37.7$, df = 3, $p < 0.001$.

Table 12

Percentage Distribution of Rear-Damaged Vehicles by Vehicle Type and Worst Injury Sustained: Oakland County (1973)

Type	K,A,B N	K,A,B %	C N	C %	No Injury N	No Injury %	Total
Full	182	2.3	1414	17.8	6333	79.9	7929
Inter.	74	2.6	518	18.2	2256	79.2	2848
Comp.	63	3.1	402	20.0	1538	76.8	2003
Sport	8	2.3	53	15.3	286	82.4	347
Jeep	0	---	4	12.9	27	87.1	31
Carryall, Van	3	3.3	8	8.8	79	87.8	90
Pickup	17	2.2	90	11.5	676	86.3	783
Truck	7	1.4	2	1.0	205	97.6	210
	357	2.4	2527	17.1	11868	80.5	14752

Table 13

Distribution of Crash-Involved Vehicles by Vehicle Type: Texas (1973) 5% Sample Vehicle File

Type	All Crashes N	All Crashes %	Rear-End Crashes Rear Damage N	Rear-End Crashes Rear Damage %	Rear-End Crashes Front Damage N	Rear-End Crashes Front Damage %
Cars	24949	84.2	3422	88.7	3559	84.0
Panel, Van	531	1.8	54	1.4	84	2.0
Pickup	3720	12.6	350	9.1	533	12.6
Trucks	433	1.5	32	0.8	59	1.4
	29633		3858		4235	

vehicles damaged in the front in rear-end collisions, the percentages of the vehicle types are very close to those for all types of crashes.

Table 14 shows the number of casualties by vehicle type in rear-damaged vehicles in Texas in 1973. The most striking feature of this table is that no injuries occurred in rear-damaged large trucks. Cars had the lowest percentage of vehicles with "no injury," with panel/vans and pickups in a middle group. (For Table 14, $X^2 = 16.2$, df = 6, $.025 < p < .01$).

Table 14

Distribution of Casualties in Rear-Damaged Vehicles by Vehicle Type and Injury Severity: Texas (1973) 5% Sample Vehicle File

	Casualties							
	K,A,B		C		No Injury		Total	
Type	N	%	N	%	N	%	N	%
Cars	90	2.1	328	7.7	3820	90.1	4238	86.7
Panel, Van	1	1.1	3	3.3	87	95.6	91	1.9
Pickup	17	3.4	27	5.4	456	91.2	500	10.2
Trucks	0	---	0	---	61	100	61	1.2
	108		358		4424		4890	

Tables 11 and 13 show that cars are overrepresented among the rear-damaged vehicles in rear-end type collisions, while trucks of all kinds, especially large trucks, are under-represented. Tables 12 and 14 show that injuries occur most frequently in rear-damaged cars and least frequently in rear-damaged large trucks. Vans and pickups form an intermediate group.

2.7 Multiply-damaged Vehicles

Collision-involved vehicles frequently incur damage to more than one area, such as damage to both the front and side of the vehicle in a single accident. Police-reported data, however, typically include adequately detailed information only on primary damage and omit any reference to secondary damage. The CPIR file, which does include secondary-damage information, was therefore used to examine the frequency with which multiply-damaged vehicles occur in a collision file and to examine injury rates for those vehicles. The percentages of multiply-damaged vehicles and the casualty rates therein are both higher than would be found in a representative accident sample because of the CPIR file bias toward severe accidents.

Table F-4 of Appendix F displays the distribution of CPIR vehicles by primary damage area, and if applicable, secondary damage area. Also displayed are the number of persons killed and injured in these vehicles on a cell-by-cell basis. From the table it can be seen that slightly more than one-third--36.0%, or 2547--of the 7,073 passenger cars and pickups have two Collision Deformation Classifications (9) recorded. The distribution of these 2,547 vehicles by the most common worst/lesser (primary/secondary) damage areas is summarized below:

Worst Damage Area/Lesser Damage Area	Frequency	%
Front/Side	637	25.0
Side/Side	578	22.7
Side/Front	226	8.9
Other/Side	218	8.6
Front/Front	196	7.7
Rear/Front	133	5.2
Other/Front	124	4.9
Front/Other	105	4.1

Each of the other eight combinations of damage areas occurs in less than 100 vehicles, and the eight together total 330 vehicles (13.0%). Of these 330 vehicles, 162 had secondary damage in the rear.

The sequence of damage-producing impacts is not recorded and collated with the CDC damage information. Therefore, whether the damage-producing impacts occurred in Front/Rear or Rear/Front order cannot be determined from the digital data.

Among passenger cars and pickups, however, it can be determined that 85 vehicles had the worst damage in the front with lesser damage in the rear, and 133 vehicles had the worst damage in the rear with lesser damage in the front. The 85 comprise 1.2% of all passenger cars and pickups and 3.3% of those with more than one CDC. The 133 comprise 1.9% of all passenger cars and pickups and 5.2% of those with more than one CDC.

In Table F-4 it is interesting to compare the cell "Primary-Front/Single Damage Area" with the cell "Primary Front/Secondary Rear" and the cell "Primary Rear/Single Damage Area" with the cell "Primary Rear/Secondary Front". The cells are shown below.

Primary Front/Single Damage Area

Fatal =	200	6.7%
Injury=	2229	75.2%
Prop.Dam.	521	17.6%
Unknown=	14	0.5%
Total =	2964	100.0%

Primary Front/Secondary Rear

Fatal =	9	10.6%
Injury=	71	83.5%
Prop.Dam.	5	5.9%
Unknown =	0	0.0%
Total =	85	100.0%

Primary Rear/Single Damage Area

Fatal =	3	1.1%
Injury=	219	79.3%
Prop.Dam.	52	18.8%
Unknown	2	0.7%
Total	276	100.0%

Primary Rear/Secondary Front

Fatal =	2	1.5%
Injury=	111	83.5%
Prop.Dam.	20	15.0%
Unknown	0	0.0%
Total =	133	100.0%

The Front/Rear/Fatal percentage (10.6%) is 1.6 times that of the Front/Single Damage/Fatal percentage (6.7%). Conversely, the Front/Single Damage/Property Damage percentage (17.6%) is 3.0 times that of the Front/Rear/Property Damage percentage (5.9%). The percentage of vehicles with rear damage and a fatality is 1.38 times higher when there is secondary front damage than when there is only one CDC. The percentage of vehicles with rear damage and with neither a fatality nor an injury is 1.25 times higher when there is no second CDC than when there is secondary front damage.

These two examples raise the possibility that when the worst damage to a vehicle is in the rear, a second damage area is not as strongly related to increased casualties as when the worst damage is in the front or elsewhere. This suggests that the area of worst impact is a more important factor than the existence of a secondary impact.

Table F-5, Appendix F, shows that 2.3% (1174/50,198) of the passenger cars involved in reportable crashes in Oakland County, Michigan in 1973 experienced both front and rear damage. And 3.7% of all the crashes in Oakland County caused both front and rear damage to at least one of the traffic units (cars, trucks, etc.) involved. These figures should probably not be generalized as statewide or national statistics, because Oakland County is extensively urban and has a large amount of expressway. However, they are probably quite representative figures for both front and rear damage to vehicles in urban areas.

2.8 Effects of Restraints in Rear-End Accidents

The interaction between lap/upper torso restraint-system usage and head restraints can be studied only in a set of data with adequate information on restraint usage (10). In the current study of restraint system effectiveness, usage of restraints is well documented and is believed to be correct. The data obtained for this study, however, do not include any detail as to the position of the head restraints. Vehicles studied include only newer (1973-1975) American-manufactured models and all of these are equipped with some sort of head restraint.

Table 15 presents the findings for front-outboard occupants of vehicles with rear-impact vectors in terms of belt use and Overall Injury Severity (AIS). The data are weighted by the inverse of the sampling fractions to reconstitute the population of new-car towaways in the sampled region.

The data do not show a significant relationship (as tested by a chi-square for injury vs. no injury). As a control, these same occupants were tested for their distribution by crash severity using the CDC as shown in Table 16. These were also not significantly different for the three belt-usage groups.

Table 17 shows the distribution of CPIR-file occupants by Overall AIS and lap-belt usage irrespective of head restraint use. No differences appear by either a Chi-square test ($X^2=5.95$; df = 7; p = 0.54) or by a modified RIDIT (11) test. From the latter it can be inferred that the probability that the belted occupants sustain the same injury severity as unbelted occupants is 0.474, and that the probability that the belted occupants sustain either a more or less severe injury is 0.263.

The conclusion is that there is no evidence of an effect of belt usage on injury severity for either set of rear-impact cases. However, the restraint-study set of data available for analysis is quite small at this time and, as always, inferences from the CPIR data must be guarded. Although not statistically significant, there are slightly fewer persons with AIS 2+ injuries who were belted in both sets of data. The likely physical effect of the belt systems would be to position the occupant so that he would be more likely to strike the head restraint in a rear impact, and one might expect some reduction in injury for those persons who were properly belted.

Table 15

Distribution of Front-Outboard Occupants by AIS and Belt Use for Rear-Impacted, 1973-1975 Vehicles: HSRI Restraint Study Data (Weighted)

		BELT USE			
		None	Lap	U. Torso	Total
AIS	0	30 (58.8%)	19 (70.4%)	39 (55.7%)	88 (59.5%)
	1	20 (39.2%)	8 (29.6%)	31 (44.3%)	59 (39.9%)
	2+	1 (2.0%)	0 (0.0%)	0 (0.0%)	1 (0.7%)
	TOTAL	51 (100%)	27 (100%)	70 (100%)	148 (100%)

N.S. P = 0.45

Table 16

Distribution of Front-Outboard Occupants by CDC Extent Code and Belt Use for Rear-Impacted 1973-1975 Vehicles: HSRI Restraint Study Data (Weighted)

		BELT USE			
		None	Lap	U. Torso	Total
CDC	0,1	18 (35.3%)	6 (22.2%)	22 (31.4%)	46 (31.1%)
	2+	33 (64.7%)	21 (77.8%)	48 (68.6%)	102 (68.9%)
	TOTAL	51 (100%)	27 (100%)	70 (100%)	148 (100%)

N.S. P = 0.49

Table 17

Distribution of Occupants by Overall AIS and Lap Belt Usage for Rear-Damaged Vehicles: CPIR File

		Belt Usage		
		Lap Belted	Not Lap Belted	Total
Overall AIS	0	49 (26.5%)	170 (27.4%)	219 (27.2%)
	1	119 (64.3%)	376 (60.5%)	495 (61.4%)
	2	12 (6.5%)	41 (6.6%)	53 (6.6%)
	3	3 (1.6%)	7 (1.1%)	10 (1.2%)
	4	1 (0.5%)	3 (0.5%)	4 (0.5%)
	5	0 (0.0%)	2 (0.3%)	2 (0.2%)
	6+	1 (0.5%)	12 (1.9%)	13 (1.6%)
	Missing Data	0 (0.0%)	10 (1.6%)	10 (1.2%)
	Total	185 (100%)	621 (100%)	806 (100%)

This interaction and its subsequent effect on injury may be more pronounced in severe impacts. In the review of the CPIR rear-impact fatalities (Appendix E), none of the fatally injured occupants were wearing restraints. Generally, however, the effect of belt usage must be small, because it is not evident in these data.

2.9 Estimates of Nationwide Frequencies: Rear-Damaged Vehicles and Whiplash Injuries

It has been shown that 5,430 vehicles exhibited rear-end damage in the Texas 5% Sample File, or 17.03% of the vehicles for which damage area was recorded. Data are **missing, however,** on 6,311 cases. On the assumption that damage to these missing-data cases is distributed the same as for those with known damage areas, it can be estimated that another 1075 vehicles would **exhibit rear damage.*** The best estimate, therefore, for the Texas 5% sample file is that 6,505 vehicles of all types had some form of rear-end damage recorded as the primary damage.

This frequency must first be extrapolated to the Texas-wide experience. From Appendix B it can be seen that the actual sampling fraction for "motor-vehicle to motor-vehicle" collisions is 0.04816 rather than the theoretical 0.05.

Texas-wide experience can be extrapolated to nationwide experience by dividing by Texas' proportion of total national vehicle miles. From Appendix C this is 0.062 for 1973. The two factors together produce an expansion factor of 334.9, which when applied to the 6505 vehicles in the 5% file produces a nationwide estimate of 2,180,000 rear-damaged vehicles for 1973.

---

*The missing data cases should be investigated to test the validity of this assumption. However, 2141 file cases were obtained by reports submitted only from drivers, and these reports do not show damage area; there is no reason to suspect bias, however.

A similar procedure applied to the 5% sample data based on collision configuration information produces a nationwide frequency estimate of 2,190,000 rear-end collisions for 1973. This number is about one-half that estimated by the National Safety Council (see Appendix D); the large discrepancy no doubt arises from differences in the source data, the methods of projecting the source data nationwide, and the definitions of the accidents being estimated.

The number of whiplash injuries occurring among rear-impacted vehicles, and hence those potentially subject to reduction by head restraints, is not, of course, available from any mass accident data file. An estimate can be obtained, however, by combining the data above with information derived from special research studies of head restraint effectiveness. Both the number of occupants subject to injury and the incidence of whiplash injury to those occupants is required.

Several outboard, front-seat occupancy figures--that is, the combined number of drivers and right-front passengers per vehicle--are available for crash populations and are tabulated below:

Data Source	Front-Outboard Occupancy
CPIR File	1.31
States (Ref. 6)	1.31
McLean (Ref. 7)	1.41
Restraint Systems Effectiveness Study:	
HSRI	1.39
CALSPAN	1.36
Southwest Research Institute	1.37

An occupancy figure of 1.38 is used subsequently.

The incidence of whiplash injuries among right-front outboard occupants without restraints in rear-impacted vehicles appears to be about 41%. From case-study follow-up investigations, States (6) established an incidence of 43.6% for all front-seat occupants whose positions were not equipped with head restraints. McLean's (7) comparable figure was 38.2%.

An estimate of the upper limit of the number of whiplash injuries potentially subject to prevention by head restraints is given by the product of the number of rear-impacted vehicles, the front-outboard occupancy rate, and the whiplash injury incidence per rear-impacted vehicles. Using 2,180,000; 1.38; and 41%, respectively, the desired estimate is 1,233,000.

The potential number of neck whiplash injuries that could be prevented by properly adjusted head restraints is a very different matter, however, and a thorough investigation is beyond the scope of this report. Both McLean and States note that the occurrence of whiplash injury is a function of occupant height, sex, and seating position. And both note the lack of statistical significance in many of their findings. Any inferences based on their data, therefore, must be considered tenuous at best.

States asserts that head restraints reduced the frequency of whiplash injury by 14%, and that fixed head restraints appear to be more effective than adjustable head restraints. The North Carolina data tend to support this general direction, but a recalculation of the North Carolina data suggests a reduction of about 5% for adjustable restraints and about 9% for fixed restraints, irrespective of other confounding factors and completely disregarding statistical considerations.

For illustration, the 14% can be applied to the 1,233,000 whiplash injuries estimated earlier. The result is a maximum potential reduction of some 172,000 whiplash injuries, about two-thirds of which would be minor. This is about one-fifth that quoted in the Comptroller General's report (5) cited in the Introduction.

3.0 SEAT SEPARATION, ACCIDENT SEVERITY, AND INJURY PATTERNS

The proposed revision of Standard 207, which specifies required performance of seat anchorages, calls for generally more rigid seating systems. Several variables in the CPIR file (and only in that file) are potentially applicable to an assessment of this specification: damage to seat adjusters, seat separation, seat cushion damage, head restraint contact and damage, backrest damage, etc. The analysis presented here was performed in terms of the seat separation variable with the view that it is most likely to show any relationship between seat performance and occupant injury.

Seat separation, if it occurs, is recorded in the CPIR file for each case vehicle at one of three points--separated at the floor, at the adjuster, or at the seat. The question we would like to answer is whether occupants are more severely injured when the seat separates in a crash than when it does not--all other things being equal. The problem is that, for a given vehicle, it seems unlikely that all other things can be equal. As experimentalists we would like to have production cars alternately fitted with "weak" and "strong" seats, and then if we identified these in the accident investigation process we could produce matched pairs for analysis. But, in fact, almost all recently manufactured cars (and the bulk of the cars in the CPIR file are recent) have been built to meet the present seat strength standard.

Some differences in the actual seat strength have been observed--largely related to car size (12). In addition, seat separation in rear-damaged cars with rear engines has been noted as being related to the mechanical stiffness of these vehicles. But unless there is some unplanned but known variation in seat strength within a given vehicle class, it will be difficult to solve the problem at hand .

3.1 Seat Separation in Front-Damaged Vehicles

With that introduction we will look to see whether some chance variation is present which would allow some inferences to be drawn in this area. First we consider only those cars whose primary impact came from the front (crash vector 11, 12, and 01 o'clock). Only injuries to the driver are examined.

Seat separation and injury severity are both positively related to crash severity as measured on the Collision Deformation Classification (CDC) scale and the Abbreviated Injury Scale (AIS). Table 18 shows the number and percentage of cars with separation (at any of the three defined points) for each level of CDC.

Table 18

Seat Separation Frequency by CDC Level, Data From CPIR File

CDC	Separated	No Separation	% Separated (row %)
1	1	796	.13
2	23	1237	1.8
3	29	613	4.5
4	29	222	11.6
5	19	96	16.5
6	16	67	19.3
7	4	18	18.2
8	5	11	31.3
9	6	31	16.2

As a first adjustment for severity, the relationship of injury to seat separation was studied at each level of CDC. A modified RIDIT (8) analysis of the overall injury distribution (on the AIS) was conducted comparing seat separation cases with non-separation cases. At each level of CDC the odds of a more severe injury with seat separation are greater than 1, as shown in Table 19. All of these are significant at better than .01.

Table 19

Odds of More Severe Injury with Seat Separation

CDC	Odds of Greater Injury
2	2.6
3	1.9
4	2.3
5	4.5
6	2.7
7-9	2.5

A more detailed analysis of injuries at CDC levels 2, 3, and 4--the bulk of accidents with seat separation in this file, and by inference in the general accident population--is presented in Table 20. This shows the odds of a driver in a car with seat separation for that particular body region. Values greater than 1 indicate increased injury levels. Thirty-six of the 45 table entries are greater than 1, and 10 of these are significant at the .05 level or less. The pattern is of generally higher injury to all body regions (except lumbar)--particularly the face, internal organs, thorax, and the right leg.

With seat separation there was an increased frequency of contact to almost any object, but especially the front hardware, instrument panel, steering assembly, and those areas near the driver's legs--foot controls, floor, and beneath the instrument panel.

Unfortunately the CDC is by no means a perfect indicator of crash severity, although it is probably the best single variable available in the CPIR file. One can argue that seat separation itself is a measure of severity--particularly in that all cars now have seats of a prescribed strength (or better) by federal mandate. Therefore, the variability of crash severity within a CDC classification was tested by tabulating the frequency of certain other characteristics of crashed vehicles, with and without seat separation.

This analysis was restricted to frontally damaged vehicles at CDC-3 level. Table 21 shows that there are a number of factors which demonstrate that the seat-separated vehicles were involved in more severe crashes, even though the CDC level is the same.

Table 20

Driver's Odds of More Severe Injury With Seat Separation by Body Region; CPIR File

Body Region	CDC		
	2	3	4
Internal Organs	1.06	1.40*	1.58*
Brain	1.13	.99	1.11
Face	1.91*	1.62*	1.56*
Head	1.33	.97	1.19
Neck	1.13	1.35	1.04
Shoulder	1.03	.93	1.03
Right Arm	1.32	1.14	.91
Left Arm	1.49	1.16	1.12
Thorax	1.54	1.68*	2.19**
Lumbar	.90(?)	.90(?)	.98(?)
Abdomen	1.01	.91	1.15
Pelvis	1.09	1.22	1.27
Right Leg	1.74*	2.58**	1.85**
Left Leg	1.12	1.02	1.31
Whole Body	.97(?)	1.02	1.09
Overall AIS	2.61**	1.92**	2.31**

* = signif. at $\leq .05$
** = signif. at $\leq .01$
(?) = probably significant, but not determined because of calculator overflow.

Table 21

Some Additional CDC-3 Crash Consequences
Which Associate with Seat Separation

	Cars with Seat Separation	Cars without Seat Separation
Pre-Crash Speed (mean)	44 mph	40 mph
Impact Speed (mean)	33 mph	30 mph
Windshield Bond Separation	50%*	13%
Lap Belt Worn	13%	22%
Pass. Compartment Reduction	74%	36%
External Object Intrusion	17%	11%
Floorpan deformation	72%	51%
Firewall deformation	67%	45%

*i.e., of the cars in CDC-3 crashes with seat separation, 50% exhibited windshield bond separation.

We conclude by observation of Table 21 that seat separation is not independent of other injury-producing or injury-increasing factors, and that it does not seem possible to separate seat-separation effects from intrusion, passenger compartment deformation, etc., in a statistical analysis sense. This is not to say that car seats should not be firmly mounted. Mathewson and Severy (13), in 1954, calculated the increased load on front-seat occupants when seat separation (in a frontal impact) occurred, and indicated that separation of the seat from its mounting does increase the potential for injury.

The data presented here on injury patterns may also be affected by other factors in the collisions which associate with seat separation. But the increases in face, thorax, and right-leg injuries are consistent with an increased load on the occupant from behind and could largely be the result of seat separation alone. The accident data can suggest that the phenomenon exists, but occupant kinematic modeling and sled tests would be a much more useful way to identify the mechanisms.

3.2 Seat Separation in Rear-End Collisions

Passenger cars in the CPIR file with rear-impact vectors (05, 06, 07 o'clock) are displayed below with respect to seat separation and CDC extent code.

CDC	Separated (Frequency)	Not Separated (Frequency)	Separated (Row % of Total)
1	4	128	3%
2	8	135	5.6%
3	10	89	10.1%
4	6	38	13.6%
5	4	32	11.1%
6	2	20	9.1%
7	0	7	0
8	0	2	0
9	1	1	50.0%

Injury data for rear-impacted vehicles with seat separation are sparse, primarily because injuries among these vehicles are infrequent, and thus few such crashes enter the CPIR file. As a first-order adjustment for severity the crashes have been divided into CDC categories 2, 3, and 4, and injury data are displayed against seat separation in Table 22.

Table 22

Injury and Seat Separation,
Passenger Cars from CPIR Files

	CDC = 2		CDC = 3*		CDC = 4	
	$\overline{SS}$	SS	$\overline{SS}$	SS	$\overline{SS}$	SS
AIS = 0,1	123	7	75	5	33	4
AIS = 2+	12	1	14	5	5	2

SS = Seat Separation, $\overline{SS}$ = Not separated.
Significant at 0.02 level.

States (6) has suggested that some forgiveness of the seating system may be beneficial in rear impacts. The data here would not refute that, although it is our opinion that the optimal design for seating-system strength can more easily be obtained from laboratory experimentation than from analyses of accident data.

3.3 Seat Separation in Side Collisions

For severe impacts, seat separation is more prevalent for side damage than for either front or rear, largely because side impact is more likely to involve direct contact with the seat. Injury data are not presented here for the side impact cases, but the frequency of seat separation at various CDC levels is shown in Table 23. Cars selected for this analysis were those with impact vectors of 02-04 o'clock and 08-10 o'clock. These data are also summarized in Figure 4 (next section).

Table 23

Seat Separation Frequency by CDC Level;
Side-Damaged Passenger Cars from the CPIR File

CDC	Separated	No Separation	% Separation (Row %)
1	0	192	0
2	8	510	1.5
3	23	574	3.9
4	34	213	13.8
5	24	67	26.4
6	20	19	51.3
7	6	5	54.5
8	3	4	42.9
9	8	14	36.4

3.4 Summary of Seat Separation Considerations

Separation of the front seat at the floor, at the adjuster, and at the seatback occurs in both frontal and rear-impacted vehicles, and the frequency of separation generally increases with impact severity. Although it is difficult to make a direct comparison of rear and front severities with parameters available in the CPIR data (i.e., the CDC) it is concluded that seat separation occurs at substantially lower crash severities for rear impacts. This observation is consistent with increased seat loading caused by the rearward displacement of occupants in rear-end crashes.

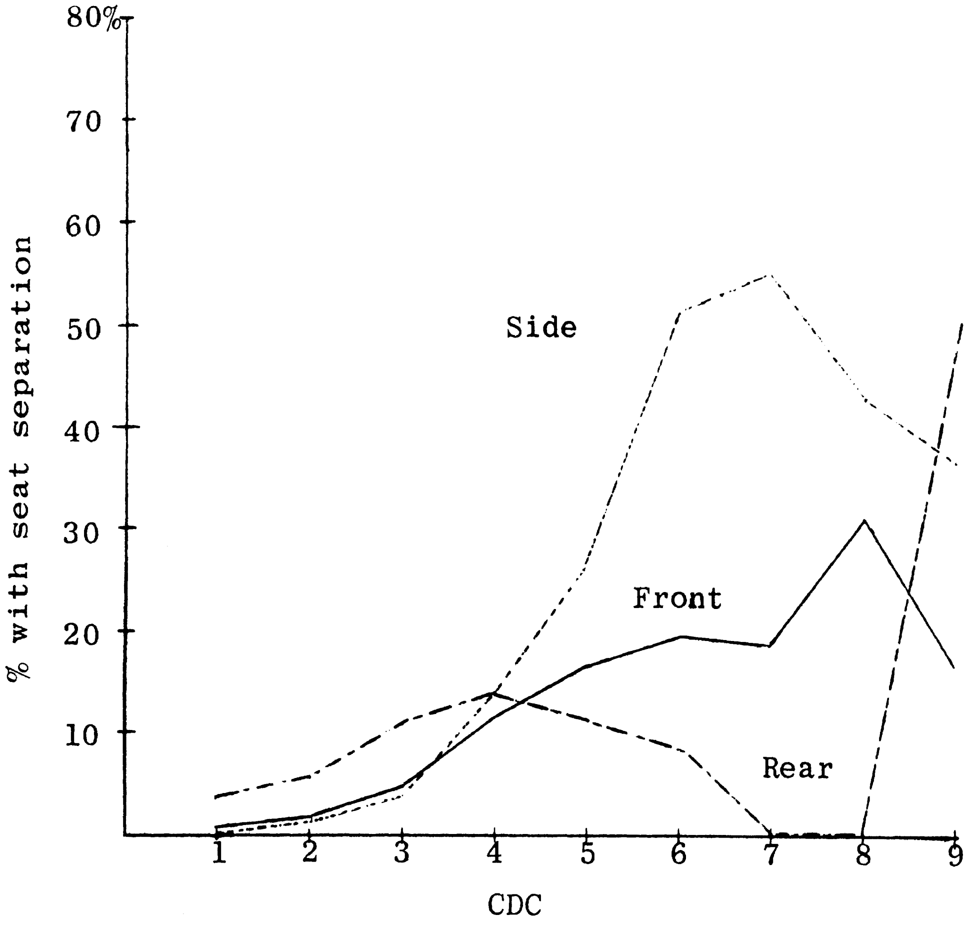
For rear impacts there is an increase in degree of driver injury associated with seat separation at CDC=3, but this could be the result of crash severity factors other than CDC above. For frontal impacts at each CDC level (above 1) injury severity is greater with seat separation. While this injury increase is associated with a number of other factors (presence of rear seat passengers, lack of belt wearing, passenger compartment intrusion, firewall and floorpan deformation) the injury patterns in the seat separation class are consistent with increased loading of the occupant from behind.

For side impacts we have not attempted to present injury as a function of seat separation, since most of the separation is the result of compartment penetration. The frequencies of seat separation for front, side, and rear collisions are summarized in Figure 4.

There are so many factors which vary in the crash data that the CPIR analysis can do no more than to identify potential problem areas and to suggest more detailed study programs. For front-seat occupants in frontal collisions there would seem to be no optimum short of an immovable seat, and the choice would have to be based on such factors as the strength of other components in the car. However, a front seat of such rigidity might not be optimal for unbelted, rear-seat passengers in frontal col-

Figure 4

Percentage of Passenger Cars with Seat Separation by CDC Damage Extent for Front, Rear, and Side Damage Areas



lisions. For front-seat occupants in rear collisions the accident data neither support nor deny the need for a more rigid seating system, although field investigators have suggested that there may be value in something less than full rigidity. Controlled laboratory tests with instrumented dummies, or simulation of occupant kinematics by computer would be more likely to identify an optimum strength than will the accident data. We assume that such controlled experimentation would precede the detailed specification of a standard.

4.0 CASUALTY PATTERNS IN REAR-IMPACTED VEHICLES

4.1 Introduction

Analysis of mass accident data has shown that rear impacts, while occurring relatively frequently, are associated with low fatality rates and reduced injury severities. This section is primarily concerned with the nature of injuries in rear-damaged passenger cars and seating system variables which may affect the frequency, type, and severity of those injuries. The CPIR File is again used, despite its biases (discussed earlier and in Appendix A), since it is the only data file available with the level of detail on both seating-system variables and occupant injuries necessary to address this question.

The CPIR file is strongly oriented toward severe-injury accidents and, since rear impacts generally produce only minor injuries, rear-damaged vehicles are not well represented in this file. The under-representation of rear-damaged vehicles has resulted in a rather small number of vehicles and occupants for this analysis. The CPIR file is also oriented toward late-model vehicles, and this restricts the number of vehicles without head restraints. The problem is further compounded by the missing-data rate on some variables, such as seat-back deflection, which is rather high (52.8% on seat back deflection). These problems significantly reduce the value of the data in this file, and frequency projections to a national experience are not warranted.

Rear-damaged passenger cars in the CPIR file were compared to rear-damaged passenger cars in the 1973 Texas 5% sample file on vehicle weight to determine if any selection bias could be detected. A significant ($p<0.0001$ by Chi-square test) difference was found in the distributions. In the Texas Sample 56.7% of the rear-damaged passenger cars weighted 3000-4000 lbs., while in the CPIR file only 42.7% of rear-damaged passenger cars were in this range. The remaining vehicles were distributed across both higher and lower weight categories, in both files. It is not known what selection procedure used by the investigators, if any, may have caused this bias. Nevertheless, it does indicate the effect of case selection on the "randomness" of this file.

No significant differences were found in occupant neck injury severities as a function of vehicle weight. Therefore, the effects of this particular bias were considered minimal for the purpose of this analysis. However, when all the CPIR file biases are considered, the effects are definitely not minimal, and conclusions based on distribution differences must take into account the possible case selection bias.

4.2 Injury Patterns

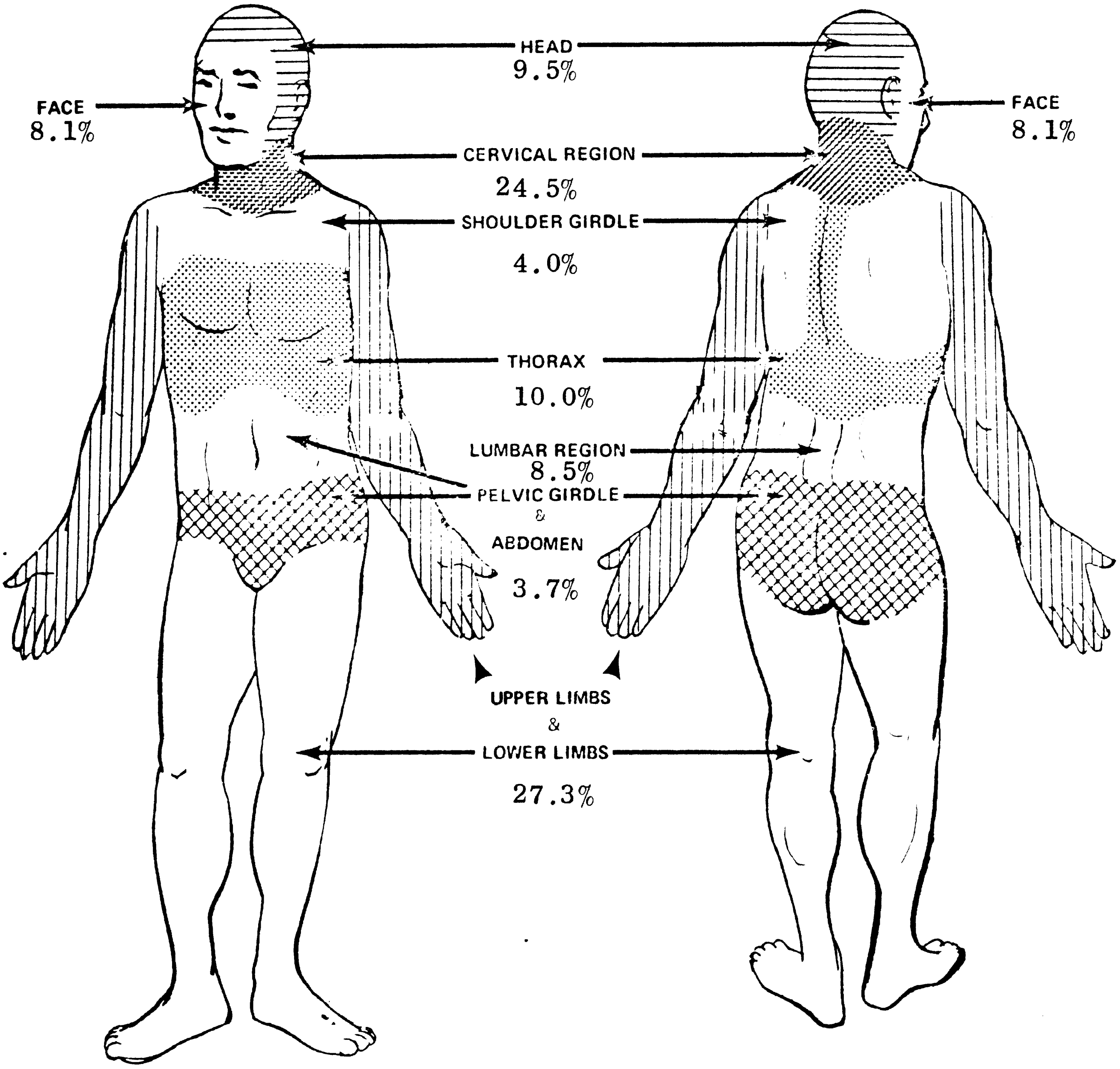
Figure 5 shows the percentage of total injuries to all occupants of rear-damaged vehicles by body region. Arms and legs (extremities), with 27.3% of the injuries, were the most frequently injured body region. However, in the total file representing all damage areas, they are also most frequently injured, with 36.1% of all injuries. It appears, therefore, that occupants of rear-damaged vehicles do not have an unusually large percentage of injuries to these regions when compared to other damage areas.

The cervical region (neck) sustained 24.5% of all injuries in rear-damaged passenger cars. When compared to all damaged vehicles,however, where the neck received only 5.3% of all injuries, this region is much more frequently injured in rear-damaged vehicles. Lower back (lumbar) injuries were also more frequent in rear-damaged vehicles, 8.5% of all injuries in rear-damaged vehicles compared to only 2.3% in all damage areas.

Upper back injuries would also be expected to be more frequent in rear damaged vehicles, since this region connects the neck and lower back. However, in the CPIR coding format, the upper back and the chest are considered to be one region--the thorax--and this combined region has 10.0% of all injuries,

Figure 5

Percentage Distribution of Injuries to Occupants of Rear-Damaged Passenger Cars by Body Region Injured



Other Regions:	Internal Organs	0.2%
	Whole Body	1.2%
	Brain	3.0%

compared with 10.6% in the whole file. This may still indicate that the upper back portion of this region is more frequently injured in rear-damaged vehicles if the chest portion of the region is less frequently injured. This makes some sense, since other frontal regions, such as the face and abdomen, are injured almost twice as frequently in all damage types (face 17.5%, abdomen and pelvis 5.7%). Unfortunately, there currently is no way to resolve this problem and therefore the thorax region is not used in this analysis. All other body regions are less frequently injured in rear-damaged passenger cars than in all damage areas combined.

The distribution of injuries by type for the body regions previously discussed is shown in Figure 6. From Table F-16, the "complaint of pain" (without visible injury) is seen to comprise 43.5% of all injuries, by far the most frequent injury type. Compared to the total file, where only 15.8% of injuries are "pain", this type of injury is over-represented in rear-damaged vehicles. "Contusions" (bruises) represent 27.8% of all injuries in rear-damaged vehicles and 28.0% of all injuries in the file. Thus "contusion" is a relatively frequent injury in all accidents, and rear-damaged vehicles are no exception. All other injury types occur relatively less frequently in rear-damaged vehicles than in other damage areas.

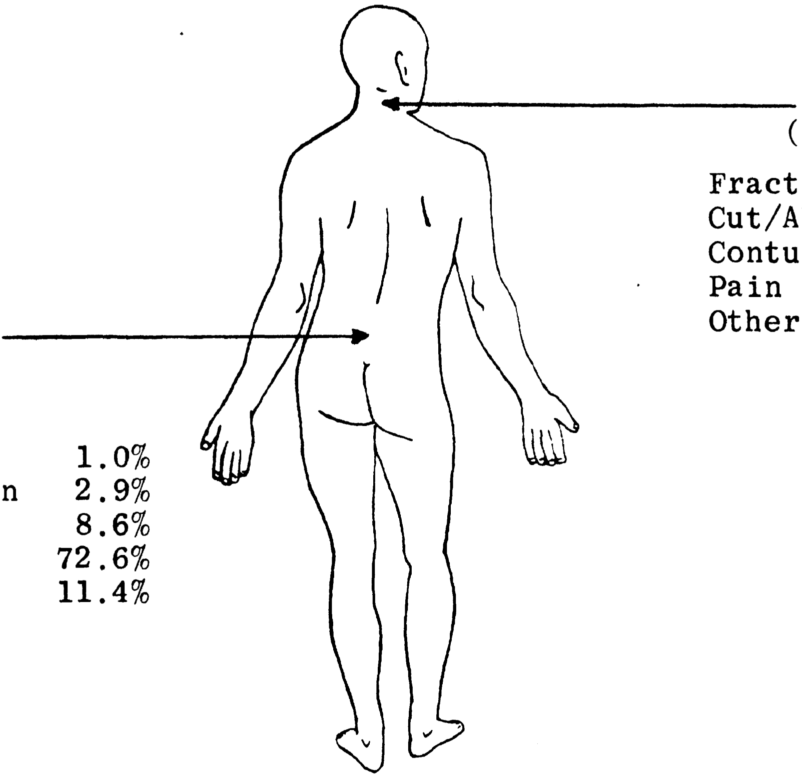
Figure 7 shows the contacts associated with injuries in rear-damaged passenger cars. "Front interior" (instrument panel, windshield, steering column, etc.) contacts are associated most frequently with injuries, followed by "impact force."*

---

*"Impact force" is a contact code in the CPIR file. Other names frequently used for the same phenomenon and included under the same contact code include "whiplash", "hyperextension", "hyperflexion," "compression", and "flexion-torsion." When the occupant makes no contact with the vehicle interior, but is injured due to his own body movement caused by the impact force, this code is used. It is also used, although infrequently, when one body region contacts the vehicle interior, such as the head, and the occupant suffers a compression injury in another body region, such as the neck. A new classification system, designed to clarify this manner of injury mechanism is currently being used. Unfortunately, enough cases are not available for present use.

Figure 6

Percentage Distribution of Injury Types for the Neck and Lower Back Regions of Occupants in Rear-Damaged Passenger Cars



Neck
(Cervical)

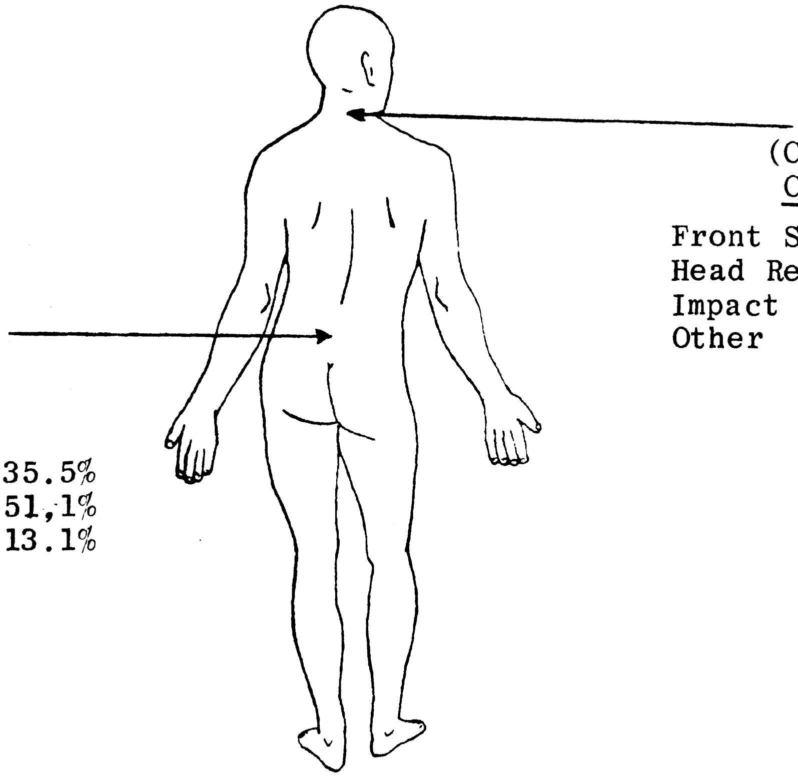
Fracture	2.3%
Cut/Abrasion	1.0%
Contusion	4.6%
Pain	79.9%
Other	12.2%

Lower Back
(Lumbar)

Fracture	1.0%
Cut/Abrasion	2.9%
Contusion	8.6%
Pain	72.6%
Other	11.4%

Figure 7

Percentage Distribution of Injury-Associated Contacts for the Neck and Lower Back Regions of Occupants in Rear-Damaged Passenger Cars



Neck
(Cervical)
Contacts

Front Seat	17.6%
Head Restraint	17.8%
Impact Force	53.4%
Other	11.2%

Lower Back
(Lumbar)

Contacts

Front Seat	35.5%
Impact Force	51.1%
Other	13.1%

It should also be noted that "impact force" injuries occur in other damage types and in other body regions. The entire file contains 924 neck "impact force" codes, 225 (24.4%) in rear-damaged vehicles; 209 thorax "impact force" codes, 49 (23.4%) in rear-damaged vehicles; and 365 lumbar "impact force" codes, 72 (19.7%) in rear-damaged vehicles. Clearly "impact force" is not solely a rear-impact phenomenon nor is it restricted to the neck.

The distribution of neck injuries associated with "impact force" by damage area indicates:

Primary Damage Area	% of all Neck "Impact force" Injuries
Front	40.9%
Side	29.2%
Rear	24.4%
Other	5.5%

It must be remembered that rear-damaged vehicles and occupants represent only 6.8% of the total file, and thus the rate of "impact force" injuries in rear-damaged vehicles is considerably higher than in other damage types.

Seating system components are frequently associated with injuries. Of all injury-producing contacts, 51.2% are associated with the seat-back, head restraint, or "impact force". This suggests the need for a more detailed analysis. The AIS coding system and the CPIR injury-associated contact format, unfortunately, do not permit such a detailed study.

A frequent set of injury types, body regions, and associated contacts can be identified in this select group of injured occupants in rear-damaged vehicles which differ from injuries received by occupants in other impact types. Typically the injuries are a "complaint of pain" in the neck or back associated with seating system failures in "impact force" contact.

The injury severity levels, measured by the AIS (Abbreviated Injury Scale), for all injuries received by all occupants of rear-damaged vehicles indicate that 89.3% were minor (AIS 1) and 5.6% were moderate (AIS 2). Since this file represents generally severe accidents, it would be expected that injury levels would be somewhat lower in a truly representative sample of rear impacts. Neck and Lower Back injuries, previously described, were found to be minor 90.7% of the time in this severe accident population.

4.3 Occupant Injury & Seating Position

The following sections deal with seating system variables and their relationship with injury severity. Three injury severity measures are used to measure the interaction of each variable with injury. Overall AIS indicates the extent of injuries regardless of body region. Neck AIS indicates the severity of injuries to the neck region only, and Lower Back AIS indicates lower back injury severity.

Overall AIS tends to mask injury severities of specific body regions when all injuries are at the same AIS. For this reason Neck and Lower Back AIS, those regions whose injuries are most frequently associated with the seating system (Appendix F Table F-15), are most often presented with respect to seating system variables.

Drivers most frequently suffered neck and back injuries in rear-damaged vehicles, and right-front passengers next most often. Of 414 drivers, 226 (54.6%) had a neck injury and 71 (40.1%) of 177 right-front occupants had a neck injury. Lower-back injuries were much less frequent in this file; only 70 (16.9%) drivers and 24 (13.6%) right-front occupants suffered any injury to this region. Rear-seat occupants had significantly fewer neck injuries (p=0.0002 by Chi-Square test); only 37 (30.1%)

of 123 had any injury to this region. However, lower back injuries were not significantly different between front and rear occupants; only 12 (9.8%) rear occupants had such an injury. Only 23 persons occupied front-seat positions other than driver or right front, and this resulted in frequencies too small to hold statistical meaning.

4.4 Occupant Injury and Head-Restraint Configuration

To determine the effect of head restraints on occupant injury and injury severity in rear-damaged vehicles, Neck and Lower Back AIS were compared for occupants with different head-restraint configurations. "Configuration" refers to both the availability and the height of the head restraint. "None" refers to vehicles not equipped with head restraints; "integral" refers to vehicles with non-adjustable head restraints. Adjustable head restraints are either "up" from the seat top or "down" on the seat top. Two problems arise from this. It is not known if the adjustment is proper for the height of the occupant seated in that position, and the adjustment is coded for the driver only. Right-front occupants with adjustable head restraints receive the same coded adjustment as the driver of their vehicle, irrespective of the actual adjustment of their head restraint. Currently there is no way to circumvent this problem other than by omitting right-front occupants of vehicles with adjustable head restraints. Right front occupants have been included, however, because of the problems relating to cell size. The right-front occupant data must be reviewed with respect to this problem.

The above-mentioned limitations notwithstanding, it was found that head restraint configuration had no significant (Chi-square tests) effect on the ratio of injury to no injury, (Appendix F, Tables F-17 to F-22). It was necessary to group all injury severities into an "injured" classification, since only 20 (3.4%) of 591 front occupants had a Neck AIS higher than 1 (minor).

4.5 Occupant Injury and Seatback Deflection

Front-seat contacts comprised 17.7% of the contacts associated with injury to occupants of rear-damaged vehicles (Figure 7). Residual front seatback deflection, as a result of front occupant contact, was compared with overall occupant AIS, with deflection divided in 5^o groupings.

The results indicate that the percentage of uninjured occupants decreases as seatback deflection increases. These results, which on the surface may appear to indicate a causal relationship, are probably more indicative of impact severity than anything else. This is analogous to the seat separation-impact severity issue in frontal impacts discussed earlier. At any rate, this finding, alone, is not sufficient to implicate seatback deflection as a causal mechanism in injury production.

When seatback deflections were grouped into those with less than 5^o deflection and those with more than 5^o deflection and subset on head restraint configuration, it was found again that head restraints had little or no effect on Overall AIS.

The data were pooled so that a RIDIT analysis (8) could be performed. For this purpose the "None" and "Down" column data were added together and considered to comprise a "No Head Restraint" category; the "Integral" and "Up" data were combined to form a "Head Restraint" category. Cases with data missing on either AIS or head-restraint adjustment were excluded. The pooled data are displayed in Tables 24 and 25.

The RIDIT analysis reveals the following for cases with less than 5 degrees seat-back deflection:

a. The probability that an occupant would incur the same AIS with or without a head restraint is 0.58.

b. The probability that an occupant would incur a lower AIS with a head restraint than without is 0.17.

c. The probability that an occupant would incur a lower AIS without a head restraint than with a head restraint is 0.25.

The analogous probabilities for Table 25 are 0.56, 0.17, and 0.27. These results are not significant ($p = 0.39$ and $p = 0.15$, respectively).

In these cases, then, an occupant is just about as well off without a head restraint as with one, with a slight preference for the former. It must be emphasized, however, that both accident-severity data and head-restraint adjustment data are far poorer than needed for conclusive results.

The same grouping of occupants on seatback deflection (less than 5° and greater than 5°) was subset on head restraint configuration and Neck and Lower Back AIS. No statistically significant (Chi-square tests) differences in injury severity, for occupants with the same head restraint configurations and different seatback deflection levels, were found for these body regions. However, occupants with more than 5° seatback deflection had a slightly higher injury rate, possibly due to having been involved in more severe crashes.

4.6 Occupant Injury and Occupant Height

Seatback "height," as measured by head restraint configuration, and occupant height were compared with injury frequency to determine if the height of the occupant might be a factor in head restraint effectiveness. Unfortunately, the only measure of occupant height available in the CPIR file is overall height, and occupant seated height would be more appropriate to this problem. There are also no data available to determine seatback height in inches, with or without a head restraint. A more precise analysis would require both.

Three groupings of front-seat occupant heights were used: 60-65 inches, 66-71 inches, and 72-77 inches. These three groupings contained 82.8% of the front-seat occupants and most of the adult, front-seat occupants.

Table 24

Distribution of Occupants in Seats which Deflected 5^{o} or Less by Overall AIS and Head Restraint Configuration

	Head Restraint	
AIS	Yes*	No*
0	10	20
1	40	46
2	1	3
3	0	0
4	0	0
5	0	0
6+	0	0
Total	51	69

Table 25

Distribution of Occupants in Seats which Deflected More Than 5^{o} by Overall AIS and Head Restraint Configuration

AIS	Yes	No
0	8	7
1	61	55
2	11	7
3	1	2
4	3	0
5	1	0
6	3	0
Total	88	71

*Yes = integral head restraint or adjusted in the "up" position.

No = no head restraint or adjusted in the "down" position.

No significant difference (Chi-square test) in Neck or Lower-Back AIS could be found either among or across these three height groupings when they were subset on head restraint configuration. Surprisingly, taller occupants, over 6 feet, had somewhat fewer neck and lower back injuries than shorter occupants, although the difference was not statistically significant.

4.7 Occupant Injury, Seating-System Variables, and Impact Severity

One measure of impact severity is the Collision Deformation Classification (CDC) extent code. This code is a single number (1-9) which is related to the amount of sheet metal crush relative to the passenger compartment. In rear-damaged vehicles an extent code greater than 5 is used when crush extends into the passenger compartment. This code is not precise, however, in that it does not take into account either the area which is damaged or the crush characteristics of the vehicle. Despite these drawbacks the CDC extent code was used to group vehicles according to collision damage. It was hoped that by doing this, possible relationships not heretofore indicated might surface on seating system variables and occupant injuries. When measured by Overall AIS it was found (Tables F-27, 28) that moderate and serious injuries (AIS 2 and greater) predictably increased with increasing levels of accident damage for both front and rear-seat occupants. A more sensitive accident severity measure might have indicated an even stronger relationship of occupant injury with vehicle damage.

The ratio of minor injuries to no injuries, on the other hand, did not show quite the same increases for front-seat occupants as for rear-seat occupants. While rear-seat occupants show an almost monotonic increase in minor and severe injury levels and a corresponding decrease in no injuries, front-seat occupant injury levels do not correspond quite so neatly. Again, a more sensitive measure of impact severity may show a more consistent relationship. It must be remembered, however, that selection criteria used by the accident investigation teams could also account for the observed disparity.

When head restraint configuration and seatback deflection were subset by accident severity a major problem arose in cell size. Although 591 occupants in seating positions normally equipped with head restraints were available for this analysis, the interaction of missing data on individual variables and a large number of variables produced very small frequencies within individual cells. No statistical significance tests could be used on data tables with many empty cells, but little effect could be noted on neck or overall injury for head restraint configuration or seatback deflection.

Groupings on the above-mentioned variables were made in an attempt to get large enough populations for statistical testing. Several groups were looked at: integral head restraints vs. no head restraint, irrespective of seatback deflection; and seatback deflection levels, irrespective of head restraint adjustment. No statistically significant differences were noted on these variables for either Overall AIS or Neck AIS when grouped in this manner. It is not possible to further determine if these non-significant relationships were the result of an insensitive measure of damage severity, case selection bias, a real-world phenomenon or some other factor.

4.8 Summary

The results of the analysis on the CPIR population of primary rear-damaged passenger cars have indicated a consistently occurring set of minor injuries in such damage types. When seating-system variable interactions are assessed to determine their effect on injury frequency and severity, little difference is found. The known biases of the CPIR file, resulting primarily from independent case selection criteria, would tend to mask small differences in minor injury rates for such variables as head-restraint configuration. Other investigators (States, 6, McLean, 7) have found moderate differences in injury rates for occupants with different head-restraint configurations. This investigation neither refutes nor supports those findings.

Impact severity was found, as expected, to be of some importance with respect to injury rates, although the measure of severity was not precise and thus the findings were not as consistent as might be expected. Generally it was found that, given an injury-producing accident (and most cases in the CPIR file are), seating-system variables appear to have little effect on minor injuries. It was found that rear-seat occupants were injured significantly less often. Whether this is due to some aspect of the seats themselves, the tendency for rear-seat occupants to be younger and smaller, or other variables is not known.

APPENDIX A

DESCRIPTION OF THE HSRI CPIR FILE

The CPIR accident data file at the UM Highway Safety Research Institute consists of computerized reports of 7,291 (January 31, 1975 update) collision-involved vehicles investigated and reported on by 22 multidisciplinary accident investigation teams since 1969 in as many different locations throughout the U.S. The file takes its name from the accident reporting form most commonly used by the investigating teams--the General Motors Collision Performance and Injury Report Long Form, Revision 3. Computerized case reports derived from that form include more than 800 variables on each accident: location, environmental conditions, possible mechanical malfunctions, collision configuration, objects contacted, driver impairment, traffic violation, legal action, type of loss, vehicle descriptions, exterior damage, steering column performance, fire, pillars, fuel tank and lines, windshield, passenger compartment, instrument panel, seats, head restraints, occupants, restraint systems, injury severities, treatment, and additional comments.

The strengths of the accident data in the HSRI CPIR file are that they are highly detailed. The data can be used by analysts to evaluate specific safety features. They can also be used to establish relationships between different variables to obtain greater insight into crash, damage, and injury mechanisms.

One major limitation of the CPIR file is that its accident cases are not a defined, representative sample of any accident, driver, or vehicle population nor of a geographic area; the data do not reflect the frequencies with which various types of accidents actually occur. Cases have never been selected for inclusion in the file on the basis of any systematic sampling plan, and therefore results obtainable from analyses of these data are not generalizable to any real-world geographic area, time period, vehicle population, or accident population. The CPIR file can in no way be considered a microcosm of the national accident population.

Although the CPIR file does not contain a representative sample of real-world accidents and their frequencies, the file has several important uses. Each case in the file can be considered a single experiment or data point in a large experimental series designed to answer questions yet to be defined. The goal of this series of "functional" experiments is to determine the functional form of the variables in relation to each other. The purposive selection of cases to be included in the file is an attempt to include in the file all levels of the independent variables of potential interest. The inclusion of a particular case adds to existing knowledge about one or more of the independent variables of interest, by extending the range, filling a gap, or providing a combination not previously reported. Because the case data include such meticulous detail, explorations of the relationships between variables can provide insight into what happens when an accident occurs. Inferences can be made concerning the degree to which changes in one variable affect levels of other variables. For example, one can compare the injuries received by occupants wearing lap restraints to those of unrestrained occupants in crashes of similar type and severity. Such findings can be viewed with caution as representative of the defined severity of crashes in the entire U.S. accident population, even though the proportions of such accidents in the CPIR file may be vastly different from those in the general population of accidents. One can make more general a finding of this sort by applying CPIR-file results to, for example, a distribution of crash severity observed in mass (police-reported) accident data. This method provides some insight into the national extent of a problem, but it is not possible to bound the errors in a statistical sense.

The CPIR case data are biased in many ways (including unknown ways) because of the variety of case-selection criteria employed by multidisciplinary teams over the years. In the early years, the teams were investigating relatively rare cases in which the relationship between crash severity and occupant injuries was unusual--cases involving fatalities in relatively minor crashes, or non-injuries in severe crashes. In later years the teams were instructed to investigate "more representative" crashes, but representativeness was not strictly defined. HSRI is now engaged in developing a data collection plan which, when put into effect on a national basis, will result in collection of multidisciplinary case data that will constitute a representative sample of all accidents in the U.S. on a continuing basis.

Appendix B

Comparison of Texas Sample Data with Statewide Data

The Texas 5% Sample Vehicle File (1973) was created from the Texas Master File by selecting every twentieth case on a pseudo-random basis. It is of interest to determine if sampling variations, on a chance basis, created significant biases in the cases that were included. Large deviations in the percentage representation of variables would need to be considered in analyses on the 5% data.

To determine which variables best matched the format of the published data from the Texas Department of Public Safety, the Texas fatal file was utilized. Since the Fatal file contains 100% of the fatal accidents in Texas for 1973, variable frequencies were matched with published frequencies to determine which file variables are directly comparable. The variables are the same in the 5% sample file as in the Fatal file; therefore, variables which match on the frequencies of fatalities or fatal crashes will match the 5% file on total crashes.

The table which follows contains the variable name, the frequencies recorded in the codebook, and the frequencies from the published accident data. The right hand column contains the ratio (in percent) of the 5% data to the published data.

The percentages range from 3.87% to 5.878% or from 22.6% low to 17.6% high. The average value for all the variables in the following table is 4.876% or 2.48% low. However, it should be noted that the variables with the lowest frequencies were responsible for the widest deviation, as would be expected.

Table B-1

Percentage Representation of Selected Variables in
Texas 5% File (1973) Compared to Published State Statistics

Variable Name	Texas 5% Sample		Texas 5% Sample	Texas Pub. Data	Sample % of Pub. Data
	Variable Number	Code Value			
Total Killed	27	1-9	189	3692	5.119
Fatal Accidents	26	1	155	3074	5.042
Injury Accidents	26	2-4	4310	87631	4.918
Property Damage Only Acc.	26	5	18066	373521	4.837
Two Motor Vehicles-head on	20	30	550	11905	4.620
Motor Vehicle to Pedestrian	19	01	256	5219	4.905
Motor Vehicle to Motor Vehicle	19	02	16100	334318	4.816
Motor Vehicle to Train	19	03	67	1256	5.334
Motor Vehicle to Parked Car	19	04	2052	41466	4.949
Motor Vehicle to Bicycle	19	05	140	2963	4.725
Motor Vehicle to Animal	19	06	308	5850	5.265
Motor Vehicle to Fixed Object	19	07	1927	40229	4.790
Motor Vehicle to Other Object	19	08	94	1921	4.893
Motor Vehicle Overturned	19	09	245	4434	5.525
Motor Vehicle Ran off Road	19	10	1216	24426	4.978
Other Non-Collision	19	11	126	2144	5.878
Passenger Car	61	01	30805	635844	4.845
Passenger Car + Trailer	61	02	73	1380	5.290
Passenger Car + House Trailer	61	03	7	166	4.217
Truck	61	04	5907	122360	4.828
Truck + Trailer	61	05	82	1875	4.373
Tractor + Semi-trailer	61	06	710	14995	4.735
Truck + House Trailer	61	07	19	335	5.672
Other Truck	61	08	31	801	3.870
Farm Equipment	61	09	9	216	4.167
Road Machinery	61	10	20	356	5.618
Bus	61	11	85	2122	4.006
School Bus	61	12	51	1223	4.170
Motorcycle	61	13	497	9911	5.015

Appendix C

Comparison of Texas and U.S. on Selected Demographic and Exposure Variables

The representativeness of any single jurisdiction's accident experience of the country as a whole is always open to question. From a consideration of the similarities and differences between Texas and the whole U.S. we have concluded that Texas is a good jurisdiction from which to generalize to the entire U.S. accident experience.

Several demographic and accident exposure parameters are presented in the following table. It can be seen that most of the parameters are consistent with each other and in good agreement with the U.S. as a whole. The Texas population density, however, is only about 3/4 of that of the whole country, and it is, of course, much less than most states. For comparison, the following population densities can be noted: California - 132; Michigan - 159; New York - 388. This difference, particularly in view of the other measures of traffic experience, is considered not to be important. Texas is also seen to be over-represented in its truck registrations and in its municipal road mileage. To these can be added the obvious weather differences; Texas clearly has less snowfall than the northern states (though perhaps not less than the U.S. average, whatever that might be), but offsetting this is that Texas probably has more rainfall than most of the states.

Total motor vehicle registrations and vehicle miles are both at 6.2% of the U.S. totals; these are two of the generally accepted traffic accident exposure measures. However, deaths per capita, deaths per vehicle, and deaths per vehicle mile are all somewhat higher than the comparable U.S. figures.

In this report the total vehicle miles have been used to extrapolate the Texas experience to the entire U.S.

Table C-1

Selected Demographic and Accident Exposure Parameters: Texas

		United States	Texas
1.	1973 population	100%	5.6%
2.	1973 population density	59.3	44.9
3.	1973 fatal accidents	100%	6.4%
4.	1973 fatalities	100%	6.7%
5.	1973 total motor vehicle registrations	100%	6.2%
6.	1973 automobile and taxicab registration	100%	5.8%
7.	1973 truck and bus registrations	100%	8.2%
8.	1972 driver licenses: total	100%	5.7%
9.	1972 driver licenses: percentage male	55.8%	54.4%
10.	1972 driver licenses: percent under 25 yr	22.1%	23.1%
11.	1972 total road mileage	100%	6.6%
12.	1972 municipal road mileage	100%	8.4%
13.	1972 rural road mileage	100%	6.3%
14.	1973 vehicle miles	100%	6.2%
15.	1973 motor vehicle traffic deaths per 100,000,000 vehicle miles	4.3	4.6
16.	1973 motor vehicle traffic deaths per 10,000 motor vehicles	4.3	4.6
17.	1973 motor vehicle traffic deaths per 100,000 population	26.6	31.3

Appendix D

Discussion of Estimates of National Accident Experience

Estimates of national accident experience can be made by several techniques, but all are subject to certain common problems. This review of some of those problems provides a perspective for viewing and using inferences and conclusions based on nationwide estimates.

1. Representativeness with respect to the phenomenon being estimated.

Many practical and theoretical issues are involved in the question of how adequately the accident experience of any single jurisdiction represents the national experience. The data presented in Appendix C show some of the reasons why we consider Texas as good as any other single jurisdiction for making nationwide projections. However, certain important differences do exist and should be kept in mind.

2. Reporting practices of the jurisdiction(s) from which projections are made.

The actual accident phenomena in two or more jurisdictions might be the same but might be reported differently. Some of the common differences in reporting practices are as follows:

a. Definitional differences. Different jurisdictions, even though they may generally follow the Uniform Vehicle Code, frequently have individual definitions of what accidents must be reported. The problem, of course, is that these definitions tend to be rather different from jurisdiction to jurisdiction. Further, there is no guarantee that motorists follow the existing statutes that govern their state. Although all states require that casualty accidents be reported--those involving death or injury--there exist significant differences about what property-damage collisions must be reported. In Texas, for example, the statutes require that an accident resulting in total property damage of $25 be reported, whereas the comparable figure in Michigan is $200.

b. Reporting methods. The "immediate notification" requirements (i.e., the obligation to inform police of an accident forthwith) vary from state to state. In Texas the requirement holds only for fatal and injury accidents. These are also required to be reported immediately in Michigan, but Michigan also requires the reporting of property-damage accidents in which the total apparent damage is $200 or more.

c. Submission of accident report forms. Additional differences exist with respect to submitting accident report forms. Texas motorists, for example,are statutorily required to file a "Driver's Confidential Report of Motor Vehicle Accident" within 10 days of an accident resulting in death, injury,or total property damage of $25 or more, and these reports are collated with the reports submitted by police officers when the official Texas data are compiled. All Michigan accident data, on the other hand, are derived from accident report forms filled in by the investigating police officer(s).

In addition to these statutory and procedural differences, differing attitudes and knowledge about the legal reporting requirements might exist among motorists from state to state. These differences could further alter the number and type of accidents that become a part of a state's official statistics.

It is commonly assumed, however, that fatal and injury-producing accidents are reported accurately.* The more severe crashes are more uniformly governed with respect to reporting requirements across jurisdictions, and they are more likely to be investigated and reported by police officers.

National Safety Council Data

Because of the problems cited above, estimates of nationwide accident experience from the National Safety Council (NSC), or from any other organization, must be used with care. Unfortunately,

---

*J.L. Recht, "The Accident Count-How NSC Gets It," Traffic Safety, September, 1968.

both NSC's input data sources and its model(s) for generating nationwide projections of fatal, injury, and property damage accident experience have not been publicly described in detail. This makes it difficult to compare NSC's published data with other data sets, and it also makes face-value acceptance of their data a questionable practice.

However, NSC data are widely quoted and used for many different purposes. The following definitions, which presumably apply to NSC published data, should be kept in mind in using their statistics:

a. "Fatal accident is an accident which results in one or more deaths within one year."

b. "Nonfatal injury accident is an accident in which at least one person is injured, and no injury terminates fatally." These are further divided with respect to injury severity. "Disabling injury is an injury causing death, permanent disability, or any degree of temporary total disability." Permanent disability is defined, but motor vehicle injury frequencies are not presented separately for this category. It should be noted, however, that "Temporary total disability" is an injury which does not result in death or permanent disability, but which renders the injured person unable to perform regular duties on one or more full calendar days after the day of the injury." The source data and the current methods for estimating injury acci-

---

*Accident Facts: 1974 Edition, National Safety Council, Chicago, 1974.

dents are both unclear, and it is unknown how injury accidents, as defined by NSC, relate to the "A","B", AND "C" injury classifications used by many states.

c. "Property damage accident is an accident which results in property damage, but in which no person is injured." To be noted is that no lower monetary limit is included in this definition, and presumably NSC's estimates under this label are for all extents of property-damage accidents.

The reader interested in pursuing these topics further is referred to Scott and Carroll.*

---

*Robert E. Scott and Philip S. Carroll, Acquisition of Information on Exposure and on Non-Fatal Crashes, Volume II: Accident Data Inaccuracies, Report 03169-II, Highway Safety Research Institute, The University of Michigan, Ann Arbor, May, 1971.

APPENDIX E

Fatal Rear Impacts in the CPIR File

Severe injuries and fatalities are relatively rare in rear-damaged vehicles. Ten fatal accidents are present in the CPIR file where one or more persons died in rear-damaged vehicles, a number small enough to allow a case-by-case review. Case-history documentation was available for review for only seven cases, representing eight fatalities. A short description is given for each at the end of this appendix.

No case was found which attributed the sole cause of death to whiplash,* although whiplash was associated with two fatalities. The most frequent cause of death was fatal head or neck injuries, all but one fatality being due to such injuries. The one exception was due to incineration by fire.

Two occupants died of fatal head and neck injuries but exact contacts were not known due to fire damage. The roof was suspected. Three drivers were fatally injured striking the roof, rear seat, or side interior and suffering fatal head or neck injuries. One of these drivers was thought to have suffered whiplash as well.

One other driver was ejected and died of head injuries from ground contact. One rear-seat occupant died of neck injuries, due either to whiplash or front-seatback contact. It should be noted that none of the occupants in any of these vehicles were wearing seat belts.

---

*Whiplash is used here as an injury type. It is used only when the crash investigators used it to describe occupant injuries.

Some of these fatally-injured-occupant positions had head restraints, some did not. Several of the vehicles contained other occupants, and most of them received only minor injuries. It is not clear that there is any pattern to the fatal injuries in this rather small group of cases, other than the fact that seven out of eight died of head and/or neck injuries. In each of these cases (except the death by fire) the investigator cites the lack of restraint usage as a critical factor in injury causation.

Fatal Rear-Impact Cases in the CPIR File

Case AA-143

This report represents the results of a multidisciplinary team investigation of a two-car collision followed by a fatal fire. One car skidded and spun across a five-lane arterial roadway at night on icy pavement. The spinning car was hit in the rear (by a car coming in the opposite direction) and its gasoline tank ruptured. The ensuing fire gutted the rear-impacted vehicle and incinerated its driver. The vehicle was equipped with integral head restraints.

Case MI-319

This report represents the results of a multidisciplinary accident investigation of a two-car front-to-rear collision followed by fire. One car turned left in an urban intersection and was struck in the rear by the second car traveling at a high rate of speed. The occupants (2) of the first car suffered fatal head and neck injuries but a post-crash fire, rollover, and extensive vehicle crush precluded determining occupant contacts. The vehicle was equipped with integral head restraints.

Case ML-71026

This report represents the results of a multidisciplinary accident investigation of a two-car, front-to-rear collision in which the driver of the rear-impacted vehicle suffered fatal injuries. One car disregarded a stop sign and struck the second car in the rear. The driver of the second car suffered fatal head injuries when he contacted the side of the vehicle interior. The other (2) occupants of the second car suffered only minor injuries. The vehicle was equipped with integral head restraints.

Case SWR 73018

This report represents the results of a multidisciplinary accident investigation of a two-car,front-to-rear expressway collision in which the driver of the rear-impacted vehicle was fatally injured. One car was proceeding at a normal speed on an expressway when rear-impacted by a second car traveling at an excessive rate of speed. The driver of the first car was ejected during a subsequent rollover and suffered fatal injuries from contact with the ground. The right-front occupant suffered minor injuries. The vehicle was equipped with adjustable head restraints.

Case UNM-32

This report represents the results of a multidisciplinary accident investigation of a two-car, front-to-rear expressway collision in which a rear-seat occupant of the rear-impacted vehicle was fatally injured. One car stopped on an urban expressway and was rear-impacted by a second car traveling at a normal speed. The driver and center-rear occupants received minor injuries, the right-front occupant was seriously injured from contact with the side of the vehicle interior. The left-rear occupant suffered extensive facial injuries from contact with a door handle, the right-rear occupant suffered fatal neck injuries. Cause of the fatal neck injuries was attributed to whiplash . However, the occupant also contacted the front seatback and ended up with her head under the front seat (which separated from its track). This 1963 model vehicle did not have head restraints.

Case UNM-39

This report represents the results of a multidisciplinary accident investigation of a two-car, front-to-rear expressway collision in which the driver of the rear-impacted vehicle received fatal head injuries. One car was travelling at a moderate speed and was struck from the rear by a second car traveling at a much higher speed. The seatback of the driver of the first car (a small import) deflected and the driver struck the rear seat with his head and suffered fatal injuries. The right-front occupant suffered minor injuries, including a sprained neck and back. The 1966 model vehicle was not equipped with head restraints.

Case UM-418

This report represents the results of a multidisciplinary accident investigation of a two-car, front-to rear collision in which the driver of the rear-impacted vehicle was fatally injured. One vehicle had just entered a four-lane roadway and was struck in the rear by a second vehicle traveling at a high rate of speed. The driver of the first vehicle suffered fatal head and neck injuries, striking the head restraint (adjusted up) and the roof. Whiplash was also considered a possible causal mechanism of his fatal neck injury.

Table F-1

National Safety Council Estimates: Fatal and Total Accidents, 1973

		Fatal			All	
	N_1	% of total	% of 2-veh.	N_2	% of total	% of 2-veh
Total Accidents	48,000** *(0.3%)	100%	----	16,600,000	100%	---
Pedestrian	9,400 (31.%)	19.5%	----	300,000	1.8%	---
Two-vehicle collision total	19,700 (0.15%)	41.0	100%	13,000,000	78.3%	100%
Angle collision	7,300 (0.2%)	15.2	37.1	4,200,000	25.3	32.3
Head-on collision	6,000 (0.9%)	12.5	30.5	700,000	4.2	5.4
Rear-end collision	2,300 (0.05%)	4.8	11.9	4,300,000	25.9	33.1
Other two-veh. coll.	4,100 (0.1%)	8.5	20.8	3,800,000	22.9	29.2
Other Collision Total	12,400 (0.5%)	25.8	----	2,500,000	15.1	---
Noncollision total	6,600 (0.8%)	13.7	----	800,000	4.8	---

* Bracketed ( ) percentages are row percentages equal to N_1/N_2 x100.

** Unbracketed percentages are column percentages referenced to that frequency labeled "100%."

Table F-2

Distribution of Vehicles and Fatalities by Collision Configuration and Damage Area: Texas (1973) Fatal Vehicle File

		Damage Area					
		Back	Front	Side	Top	Not. Applic. Missing Data	Total
Collision Configuration	Rear-end	113/42	164/98	64/40	24/18	49/31	414/229
	Head-on	13/7	828/555	380/336	21/12	77/67	1329/977
	Side-Swipe	9/6	23/12	36/12	7/5	10/6	85/41
	Angle	9/3	389/102	358/322	22/17	61/50	839/494
	Other	1/0	1/0	3/2	0/0	1/1	6/3
	Single-Vehicle	19/16	763/475	332/265	398/418	923/752	2435/1926
	Total	164/74	2178/1242	1173/977	472/470	1121/907	5108/3670

*N1/N2 denotes that N2 persons died in N1 vehicles.

Table F-3

Distribution of Vehicles by Collision Configuration and Damage Area: Texas (1973) 5% Sample Vehicle File

		Damage Area					
		Back	Front	Side	Top	Not Applicable, Missing Data	Total
Collision Configuration	Rear-end	3967	4423	2553	10	2199	13,152
	Head-On	247	1818	1622	7	685	4,379
	Side-Swipe	172	512	1466	8	546	2,704
	Angle	421	3839	5018	12	1583	10,873
	Other	249	138	526	1	278	1,192
	Single-Vehicle	374	2537	1514	452	1987	6,864
	Total	5430	13,267	12,699	490	7278	39,164

Table F-4

Frequencies of Combinations of Damage Areas and Their Severities: Pass. Cars and Pickups -- CPIR File

	Primary Damage	Single Damage Area	Secondary Damage				
			Front	Rear	Side	Other	Total
Front	No. of Vehicles	2964	196	85	637	105	3987
	No. Killed	200	19	9	49	19	296
	No. Injured	2229	159	71	538	75	3072
	Property Damage	521	15	5	50	10	601
	Unknown	14	3	0	0	1	18
Rear	No. of Vehicles	276	133	5	38	11	463
	No. Killed	3	2	1	3	1	10
	No. Injured	219	111	3	25	9	367
	Property Damage	52	20	1	10	1	84
	Unknown	2	0	0	0	0	2
Side	No. of Vehicles	1093	226	56	578	93	2046
	No. Killed	115	30	7	70	21	243
	No. Injured	773	179	47	447	63	1509
	Property Damage	200	17	2	59	9	287
	Unknown	5	0	0	2	0	7
Other	No. of Vehicles	193	124	16	218	26	577
	No. Killed	34	16	4	43	6	103
	No. Injured	125	98	11	150	19	403
	Property Damage	32	10	1	25	0	68
	Unknown	2	0	0	0	1	3
Total	No. Vehicles	4526	679	162	1471	235	7073
	No. Killed	352	67	21	165	47	652
	No. Injured	3343	547	132	1160	166	5348
	Property Damage	808	62	9	144	20	1043
	Unknown	23	3	0	2	2	30

Table F-5

Distribution of Front-and-Rear Damaged Vehicles and All Damaged Vehicles by Vehicle Type in the 1973 Oakland County File

	Damage Areas					
	Front and Rear		All Others		Total	
Type of Vehicle	N	Col %	N	Col %	N	Col %
Passenger Cars	1174	(91.0)	49,744	(81.6)	50,198	(81.8)
Station Bus, Carryall, etc.	11	(0.9)	381	(0.6)	392	(0.6)
Jeep Type	1	(0.0)	148	(0.2)	149	(0.2)
Pickup or Panel Truck	68	(5.3)	3,213	(5.3)	3,281	(5.3)
Other, Unknown Not Applicable	36	(2.8)	7,500	(12.3)	7,536	(12.1)
Total	1290	(100)	60,986	(100)	62,276	(100)

Frequency of Front-and-Rear Damage Accidents in the 1973 Oakland County File

	Frequency	
Both Front and Rear Damage to One or More Traffic Units	1282	(3.7%)
No Traffic Units with Both Front and Rear Damage	33,651	(96.3%)

Table F-6

Distribution of Vehicles and Casualties by TAD Damage Area and Severity: Texas (1973)
5% Sample Vehicle File

Damage Severity		Vehicle Damage Area				
		Back	Front	Side	Top	Total
0	No. of Vehicles	317	362	234	-0-	913
	K Injuries	-0-	-0-	-0-	-0-	-0-
	A Injuries	-0-	-0-	-0-	-0-	-0-
	B Injuries	1	-0-	2	-0-	3
	C Injuries	1	1	7	-0-	9
1	No. of Vehicles	2920	4647	4983	18	12568
	K Injuries	-0-	-0-	-0-	-0-	-0-
	A Injuries	-0-	6	3	-0-	9
	B Injuries	10	55	17	3	85
	C Injuries	139	59	58	3	259
2	No. of Vehicles	1320	3621	3919	47	8907
	K Injuries	-0-	-0-	3	-0-	3
	A Injuries	3	27	12	3	45
	B Injuries	21	145	102	10	278
	C Injuries	112	129	156	5	402
3	No. of Vehicles	628	2767	2445	122	5962
	K Injuries	-0-	3	1	1	5
	A Injuries	6	92	46	4	148
	B Injuries	29	343	221	21	614
	C Injuries	127	243	252	11	633
4	No. of Vehicles	148	1076	596	103	1923
	K Injuries	-0-	1	1	2	4
	A Injuries	6	176	62	20	264
	B Injuries	39	386	224	47	696
	C Injuries	69	200	131	18	418
5	No. of Vehicles	43	357	258	73	731
	K Injuries	-0-	4	7	5	16
	A Injuries	2	99	47	8	156
	B Injuries	8	179	96	46	329
	C Injuries	7	85	62	16	170
6	No. of Vehicles	32	260	155	60	507
	K Injuries	-0-	4	10	6	20
	A Injuries	2	90	42	15	149
	B Injuries	7	118	74	32	231
	C Injuries	23	63	38	12	136
7	No. of Vehicles	22	177	109	67	375
	K Injuries	2	47	34	16	99
	A Injuries	1	109	68	33	210
	B Injuries	9	100	44	37	190
	C Injuries	4	23	15	10	52
Missing Data, Not Applicable	No. of Vehicles					7278
	K Injuries					42
	A Injuries					273
	B Injuries					572
	C Injuries					283
Total	No. of Vehicles	5430	13267	12699	490	39164
	K Injuries	2	59	56	30	189
	A Injuries	20	598	280	83	1254
	B Injuries	124	1326	780	196	2998
	C Injuries	482	803	719	75	2362

Table F-7

Distribution of Rear-Damaged Vehicles and Casualties by Vehicle Type and Vehicle Weight in the Texas (1973) 5% Sample Vehicle File*

Weight (pounds)		Pass. Cars	Multi-Purpose Vehicles	Pickups	Trucks	Farm Equipment, Bus, Machines, Motorcycles	Pedestrians, Other, Missing Data	Total
Motor-Cycles	No. Veh.	3						3
	K Inj.							
	A Inj.							
	B Inj.							
	C Inj.	1						1
1500-2000	No. Veh.	303	6	7			1	317
	K							
	A	2						2
	B	19						19
	C	32						32
2000-2500	No. Veh.	230	1	3			5	239
	K							
	A	2						2
	B	14						14
	C	16	1					17
2500-3000	No. Veh.	483					1	484
	K							
	A	1						1
	B	6						6
	C	67						67
3000-3500	No. Veh.	1111					8	1119
	K							
	A	1						1
	B	18						18
	C	109						109
3500-4000	No. Veh.	1399	1	34	1		14	1499
	K	1						1
	A	8						8
	B	29						29
	C	118		2				120
4000-4500	No. Veh.	410					2	412
	K	1						1
	A	1						1
	B	6						6
	C	34						34
4500-5000	No. Veh.	298					8	306
	K							
	A							
	B	2						2
	C	28					1	29
5000-5500	No. Veh.	27					1	28
	K							
	A							
	B	1						1
	C	5						5
Trucks	No. Veh.	7	12	44	26	17	62	168
	K							
	A							
	B			1	1			2
	C	2		3			1	6
Other, Misc., Unclass, Unknown	No. Veh.	237	93	462	46	6	61	905
	K							
	A	2		3				5
	B	7	4	16				27
	C	30	2	29			1	62
Total	No. Veh.	4508	113	550	73	23	163	5430
	K	2						2
	A	17		3				20
	B	102	4	17	1			124
	C	442	3	34			3	482

* Blank spaces indicate empty cells.

Table F-8

CPIR File Distribution on Variables of Interest as of January 19, 1975

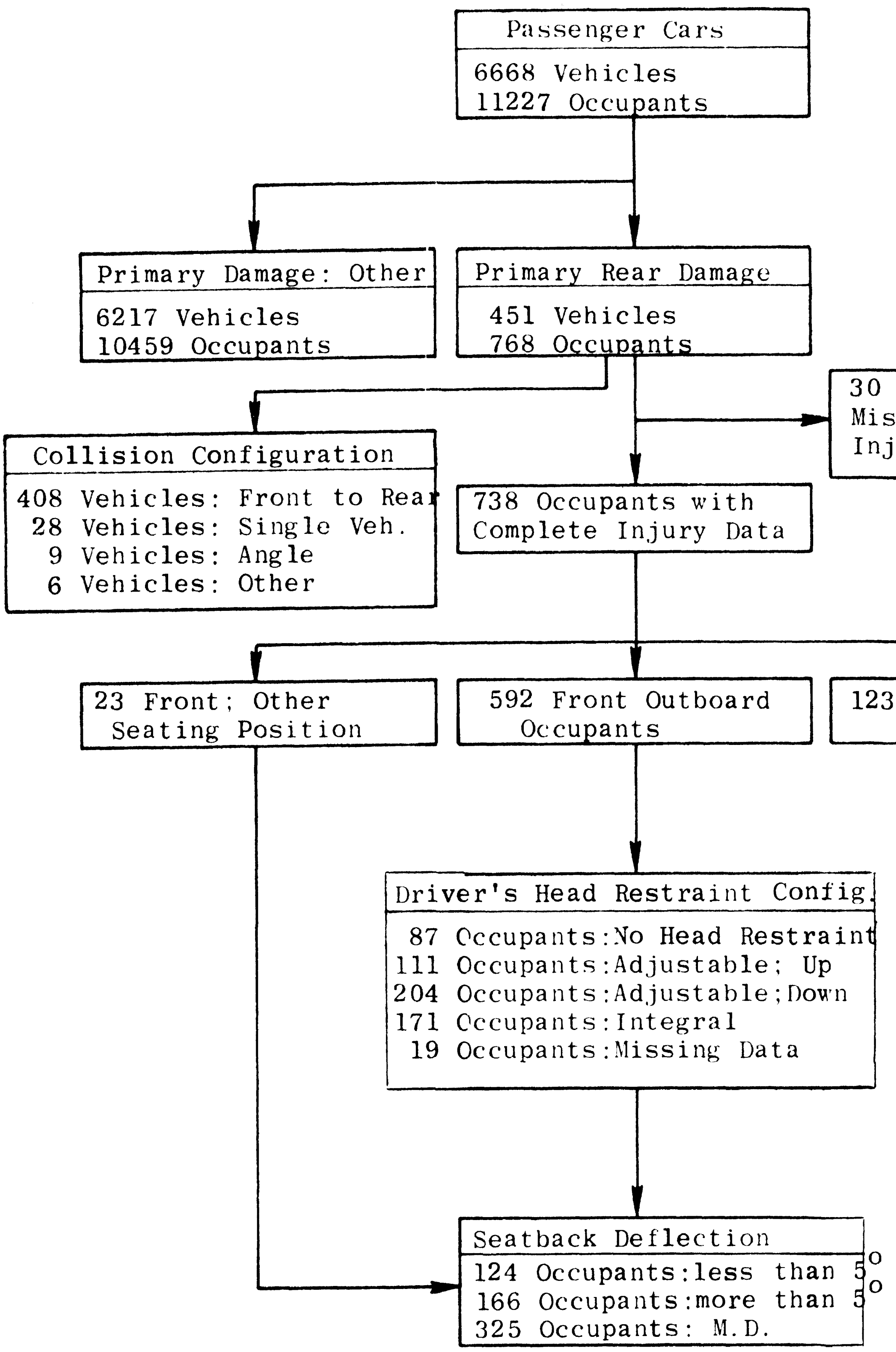


Table F-9

Distribution of Rear-Damaged Passenger Cars in the CPIR File by Model Year

Model Year	Freq.	%
1959	1	0.2
1961	2	0.4
1962	4	0.9
1963	3	0.7
1964	2	0.4
1965	12	2.7
1966	8	1.8
1967	12	2.7
1968	29	6.4
1969	44	9.8
1970	89	19.7
1971	97	21.5
1972	88	19.5
1973	54	12.0
1974	6	1.3
Total	451	100.0

% of File 6.8%

Table F-10

Distribution of Rear-Damaged Passenger Cars in the CPIR and Texas 5% Sample Files by 500-Pound Weight Classes, Missing Data Excluded

	CPIR Freq.	Col %	Texas 5% Freq.	Col %
1-1499	1	0.2	3	0.1
1500-1999	36	8.0	317	7.0
2000-2499	54	12.0	239	5.3
2500-2999	54	12.0	484	10.7
3000-3499	92	20.4	1119	24.7
3500-3999	105	23.3	1449	32.0
4000-4499	81	18.0	412	9.1
4500-4999	19	4.2	306	6.8
5000-5499	4	.9	28	.6
Other	5	1.1	168	3.9
Total	451		4525	
% of File	6.8			

($p < 0.0001$, by X^2 test)

Table F-11

Distribution of Drivers and Right-Front Passengers of Rear-Damaged Passenger Cars by Vehicle Weight and Occupant Neck AIS

	Weight of Vehicle (lbs.)							
Neck AIS	1500-1999	2000-2499	2500-2999	3000-3499	3500-3999	4000-4499	4500 +	Total
0 (None)	33	33	37	56	70	56	11	296
Column %	60.0	48.5	49.3	45.5	52.2	50.5	33.3	49.4
1	16	35	34	66	58	53	20	282
	29.1	51.5	45.3	53.7	43.3	47.7	60.6	47.1
2	3		3	1	4	2	2	15
	5.5		4.0	0.8	3.0	1.8	6.1	2.5
3	0		1		1			2
			1.3		0.7			0.3
4	1							1
	1.8							0.2
5	1							1
	1.8							0.2
6	1				1			2
	1.8				0.7			0.3
Total	55	68	75	123	134	111	33	599
Row %	9.2	11.4	12.5	20.5	22.4	18.5	5.5	

(N.S. by X^2 test)

Table F-12

Distribution of Occupant Injuries by Body Region Injured in Rear-Damaged Vehicles

Body Region	REAR-DAMAGED VEHICLES Freq.	%	% of file	TOTAL FILE freq.	%
Internal Organs	2	0.2	0.2	882	2.7
Brain	37	3.0	2.4	1528	4.7
Face	100	8.1	1.8	5703	17.5
Head	117	9.5	3.6	3253	10.0
Neck	303	24.5	17.4	1739	5.3
Shoulders	50	4.0	3.8	1310	4.0
Chest & Upper Back	124	10.0	3.6	3463	10.6
Lower Back	105	8.5	14.1	746	2.3
Abdomen & Pelvis	46	3.7	2.5	1850	5.7
Extremities	338	27.3	2.9	11759	36.1
Whole Body	15	1.2	4.0	379	1.2
	1237	100.0	3.8	32612	100.0

Table F-13

Distribution of Occupant Injuries by
Type of Injury in Rear-Damaged Vehicles

Type	REAR DAMAGED VEHICLES Freq.	%	% of file	CPIR TOTAL FILE freq.	%
Fracture	40	3.2	1.1	3606	11.1
Laceration	109	8.8	1.7	6436	19.7
Contusion	344	27.8	3.8	9126	28.0
Pain *	538	43.5	10.4	5158	15.8
Abrasion	81	6.5	1.7	4754	14.6
Concussion	31	2.5	3.3	944	2.9
Burn	5	0.4	4.2	120	0.4
Hemorrhage	10	0.8	1.1	921	2.8
Other	79	6.4	5.1	1547	4.7
Total	1237	100.2	2.8	32612	100.0

*"Pain" is ordinarily assigned as an injury type only at AIS level 1 (533 of 538 cases). In this set of data there are 5 assignments of "pain" at AIS-2. AIS-2 requires "severe complaints with anatomical or radiological evidence..." (of injury). For more detail see: "Rating the Severity of Tissue Damage", JAMA, Vol. 215, No. 2, Jan., 1971.

Table F-14

Distribution of Contacts Associated[*] with 1237 Injuries to 673 Occupants in Rear-Damaged Passenger Cars

	Frequency	% Total
Front Interior	407	27.0
Roof	33	2.2
Side Interior	145	9.6
Seats	267	17.7
Belt System	23	1.5
Head Restraint	117	7.8
Hyperextension/ hyperflexion (impact force)	387	25.7
Other	126	8.4
Total	1505	100.0

---

[*] A minimum of 1 and a maximum of 4 contacts are associated with each injury. The number of contacts coded depends on the investigator's and occupant's opinion of which contact (if there was more than one) caused the injury. If there was more than one possible cause, then <u>all</u> possible (up to four) injury producing contacts are coded.

Table F-15

Distribution of Associated Contacts for 1237 Injuries by Selected Contact Areas and Body Regions in Rear-Damaged Vehicles

Area Contacted	HEAD freq.	HEAD col %	NECK freq.	NECK col %	CHEST & UPPER BACK freq.	CHEST & UPPER BACK col %	LOWER BACK freq.	LOWER BACK col %	OTHER freq.	OTHER col %	TOTAL freq.	TOTAL col %
Front seat	26	8.0	74	17.6	50	26.9	50	35.5	50	3.7	250	10.3
Head restraint	28	8.6	75	17.8	10	5.4	0	0	4	0.3	117	4.8
Hyperextension/ hyperflexion (whiplash)	7	2.1	225	53.4	49	26.3	72	51.1	34	2.5	387	15.9
Other	265	81.3	47	11.2	77	41.4	19	13.5	1274	93.5	1682	69.0
Total (row %)	326	(13.4)	421	(17.3)	186	(7.6)	141	(5.8)	1362	(55.9)	2436	100.0
	Distribution of 1237 Injuries by Selected Injury Types and Body Regions											
Injury Type												
Fracture	7	2.8	7	2.3	10	8.1	1	1.0	15	3.3	40	3.2
Cut/Abrasion	82	32.3	3	1.0	2	1.6	3	2.9	100	22.1	190	15.4
Contusion	84	33.1	14	4.6	31	25.0	9	8.6	206	45.6	344	27.8
Pain	36	14.2	242	79.9	72	58.1	80	76.2	108	23.9	538	43.5
Concussion	25	9.8	0	0	0	0	0	0	6	1.3	31	2.5
Other	19	7.5	37	12.2	9	7.3	12	11.4	17	3.8	94	7.6
Total (row %)	254	(20.5)	303	(24.5)	124	(10.0)	105	(8.5)	452	(36.5)	1237	100.0

Table F-16

Distribution of 1237 Injuries by Body Region Injured and Injury Severity in Rear-Damaged Vehicles

Body Region	AIS 1 freq.	1 col %	2 freq.	2 col %	3 freq.	3 col %	4 freq.	4 col %	5 freq.	5 col %	6 freq.	6 col %	Missing Data freq.	Missing Data col %	Total freq	Total col %
Brain	12	1.1	12	17.4	1	3.2	5	50.0	0	0	7	46.7	0	0	37	3.0
Face	92	8.3	7	10.1	1	3.2	0	0	0	0	0	0	0	0	100	8.1
Head	107	9.7	4	5.8	3	9.7	0	0	2	40.0	1	6.7	0	0	117	9.5
Neck	273	24.7	18	26.1	3	9.7	3	30.0	1	20.0	5	33.3	0	0	303	24.5
Upper Back & Chest	104	9.4	7	10.1	12	38.7	1	10.0	0	0	0	0	0	0	124	10.0
Lower ack	97	8.8	5	7.2	3	9.7	0	0	0	0	0	0	0	0	105	8.5
Other	420	38.0	16	23.2	8	25.8	1	10.0	2	40.0	2	13.3	2	100	451	36.5
Total	1105		69		31		10		5		15		2		1237	
Row % of Total	89.3		5.6		2.5		0.8		0.4		1.2		0.2		100	

Distribution of 1237 Injuries by Type of Injury and Injury Severity

Injury Type	AIS 1 freq.	1 col %	2 freq.	2 col %	3 freq.	3 col %	4 freq.	4 col %	5 freq.	5 col %	6 freq.	6 col %	Missing Data freq.	Missing Data col %	Total freq	Total col %
Fracture	8	0.7	10	14.5	12	38.7	2	20.	2	40.	5	33.3	1	50.	40	3.2
Laceration/ Abrasion	169	15.3	13	18.8	4	12.9	0	0	0	0	4	26.7	0	0	190	15.4
Contusion	329	29.8	4	5.8	6	19.4	4	40.	0	0	1	6.7	0	0	344	27.8
Pain	533	48.2	5	7.2	0	0	0	0	0	0	0	0	0	0	538	43.5
Concussion	11	1.0	11	15.9	1	3.2	3	30.	2	40.	2	13.3	1	50.	31	2.5
Other	54	4.9	26	37.7	8	25.8	1	10.	1	20.	3	20.	0	0	94	7.6
Total	1105		69		31		10		5		15		2		1237	
Row % of Total	89.3		5.6		2.5		0.8		0.4		1.2		0.2			

TOTAL FILE	AIS 1	2	3	4	5	6	Missing Data	Total
Total Frequency	23,305	4369	2153	840	582	1265	98	32,612
Row %	71.5	13.4	6.6	2.6	1.8	3.9	0.3	100

Table F-17

Distribution of All Occupants in Rear-Damaged Passenger Cars by Seating Position and Neck/Lower Back AIS

Seating Position

Neck AIS	Driver		Rt. Front		Other Front		Rear		Other		Total	
		Col %		Col %								
0	188	45.4	106	59.9	14	60.9	84	68.3	1	100	393	53.3
1	212	51.2	64	36.2	8	34.8	35	28.5			319	43.2
2	9	2.2	6	3.4	1	4.3	2	1.6			18	2.4
3	2	.5	0				0				2	.3
4	1	.2	0								1	.1
5	1	.2	0								1	.1
6	1	.2	1	.6			2	1.6			4	.5
Total	414		177		23		123		1		738	
Row %	56.1		24.0		3.1		16.7		.1			

(Collapsed to Injury vs. No Injury, p = 0.0002, by x^2 test)

Lower Back AIS	Driver		Rt. Front		Other Front		Rear		Other		Total	
0	344	83.1	153	86.4	18	78.3	111	90.2	1	100	627	85.
1	67	16.2	20	11.3	4	17.4	12	9.8			103	14.
2	2	.5	3	1.7	0						5	.7
3	1	.2	1	.6	1	4.3					3	.4
4-6												
Total	414		177		23		123		1		738	
Row %	56.1		24.0		3.1		16.7		.1			

(Collapsed to Injury vs. No Injury, p=0.0827 by x^2 test)

Table F-18

Distribution of Drivers and Right-Front Occupants by Neck AIS and Head Restraint Configuration

DRIVERS ONLY

			Head Restraint Configuration									
	MD*		None		UP		Down		Integral		Total	
Neck AIS		Col%		Col%		Col%		Col%		Col%		Col%
0	8	57.1	27	45.8	34	47.9	61	42.7	58	45.7	188	45.4
1	4	28.6	28	47.5	35	49.3	80	55.9	65	51.1	212	51.2
2	1	7.1	3	5.1			2	1.4	3	2.4	9	2.2
3	1	7.1			1	1.4					2	0.5
4									1	0.8	1	0.2
5			1	1.7							1	0.2
6					1	1.4					1	0.2
Total	14		59		71		143		127		414	

RIGHT-FRONT OCCUPANTS ONLY

(Adjustable: Position Unk.)

Neck AIS												
0	4	100	19	67.9	20	50.0	38	62.3	25	56.8	106	59.9
1			8	28.6	19	47.5	19	31.1	18	40.9	64	36.2
2			1	3.6	1	2.5	4	6.6			6	3.4
3												
4												
5												
6									1	2.3	1	0.6
Total	4		28		40		61		44		177	

* Missing Data (Tables combined and Collapsed to Injury vs. No Injury, p = 0.9129 by x^2 test)

Table F-19

Distribution of Occupants <u>Without</u> Head Restraints by Seating Position and Neck/Lower Back AIS

	Seating Position											
	Driver		Right Front		Other Front		Rear		Other		Total	
		Col %		Col %		Col %		Col %		Col %		Col %
Neck AIS												
0	27	45.8	19	67.9	2	50.0	16	76.2	1	100.0	65	57.5
1	28	47.5	8	28.6	2	50.0	3	14.2			41	36.3
2	3	5.1	1	3.6							4	3.5
3												
4												
5	1	1.7									1	1.9
6							2	9.5			2	1.8
Total	59		28		4		21		1		113	
Row %	52.2%		24.8%		3.5%		18.6%		0.9%			
Lower Back AIS												
0	51	86.4	23	82.1	2	50.	20	92.5	1	100.0	97	85.8
1	8	13.6	4	14.3	1	25.	1	4.8			14	12.4
2												
3			1	3.6	1	25.					2	1.8
4												
5												
6												
Total	59		28		4		21		1		113	

Table F-20

Distribution of Occupants with Drivers Head Restraint Adjusted Down on Seat Top by Seating Position and Neck/Lower Back AIS

	Seating Position									
	Driver		Right Front		Other Front		Rear		Total	
		Col%		Col%		Col%		Col%		Col%
Neck AIS										
0	61	42.7	38	62.3	6	66.7	25	56.8	130	50.6
1	80	55.9	19	31.1	2	22.2	19	43.2	120	46.7
2	2	1.4	4	6.6	1	11.1			7	2.7
3										
4										
5										
6										
Total	143		61		9		44		257	
Row %	55.6		23.7		3.5		17.1			
Lower Back AIS										
0	117	81.8	54	88.5	7	77.8	39	88.6	217	84.4
1	24	16.8	6	9.8	2	22.2	5	11.4	37	14.4
2	2	1.4	1	1.6					3	1.2
3										
4										
5										
6										
Total	143		61		9		44		257	

Table F-21

Distribution of Occupants of Vehicles with Drivers Head Restraint Adjusted Up from Seat Top by Seating Position and Neck/Lower Back AIS

	Seating Position									
	Driver		Right Front		Other Front		Rear		Total	
		Col %		Col %		Col %		Col %		Col %
Neck AIS										
0	34	47.9	20	50.	4	66.7	20	76.9	78	54.5
1	35	49.3	19	47.5	2	33.3	4	15.4	60	42.0
2			1	2.5			2	7.7	3	2.1
3	1	1.4							1	0.7
4										
5										
6	1	1.4							1	0.7
Total	71		40		6		26		143	
Row %	49.7		28.0		4.2		18.2			
Lower Back AIS										
0	56	78.9	33	82.5	6	100	25	92.3	119	83.2
1	14	19.7	5	12.5			2	7.7	21	14.7
2			2	5.0					2	1.4
3	1	1.4							1	0.7
4										
5										
6										
Total	71		40		6		26		143	

Table F-22

Distribution of Occupants with Integral Head Restraints by Seating Position and Neck/Lower Back AIS

	Seating Position											
	Driver		Right Front		Other Front		Rear		Other		Total	
		Col %		Col %		Col %		Col %		Col %		Col %
Neck AIS												
0	58	45.7	25	56.8	2	50.	23	71.9			108	52.2
1	65	51.2	18	40.9	2	50.	9	28.1			94	45.4
2	3	2.4									3	1.4
3												
4	1	0.8									1	0.5
5												
6			1	2.3							1	0.5
Total	127		44		4		32					
Row %	61.4		21.3		1.9		15.5				207	
Lower Back AIS												
0	107	84.3	40	90.9	3	75.0	28	87.5			178	86.0
1	20	15.7	4	9.1	1	25.0	4	12.5			29	14.0
2												
3												
4												
5												
6												
Total	127		44		4		32				207	

Statistical Test Results for Tables F-19 - F-22.

Seating Position	X^2 Probability[1]
Drivers	0.5243
Right Front	0.5322
Rear	0.0258

Seating Position	X^2 Probability[2]
Drivers	0.5243
Right Front	0.1275
Rear	0.7289

[1] The probabilities given are the result of x^2 tests of 4 x 2 contingency tables formed by selecting like seating positions from tables - and combining AIS's into an injury-no injury binary variable.

[2] The probabilities given are the result of x^2 tests of 2 x 2 contingency tables formed by selecting like seating positions from tables - , combining head restraint configurations "integral" with "up" and "down" with "none", and combining AIS's into an injury-no injury binary variable.

Table F-23

Distribution of Front-Seat Occupants in Rear-Damaged Passenger Cars by Seatback Deflection and Overall Injury Severity

		Seatback Deflection								
		0°	$1-5^{\circ}$	$5-10^{\circ}$	$10-15^{\circ}$	$15+^{\circ}$	Rotation Unk.	Rotated: Unknown Amount	Total	% Total
Overall AIS	0	23	8	8	3	4	6	92	144	23.4
	1	56	32	42	25	53	26	163	397	64.6
	2	3	2	3	5	11	3	19	46	7.5
	3	0	0	4	0	0	0	4	8	1.3
	4	0	0	1	0	1	0	2	4	0.7
	5	0	0	0	0	1	1	0	2	0.3
	6+	0	0	2	0	0	0	4	6	1.0
	M.D.	0	0	1	0	1	0	6	8	1.3
	Total	82	42	61	33	71	36	290	615	100.0
	% Total	13.3	6.8	9.9	5.4	11.5	5.8	47.2	100	

Table F-24

Distribution of Occupants in Seats with 5° Seatback Deflection or Less by Overall Injury Severity and Head Restraint Configuration

AIS	None	Integral	Up	Down	M.D.	Total
	Head Restraint Configuration					
0	1	9	1	19	1	31
1	10	33	7	36	0	86
2	0	0	1	3	0	4
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6+	0	0	0	0	0	0
M.D.	0	0	0	0	0	0
Total	11	42	9	58	1	121

Distribution of Occupants in Seats with More than 5° of Seatback Deflection by Overall Injury Severity and Head Restraint Configuration

AIS	None	Integral	Up	Down	M.D.	Total
0	1	5	3	6	0	15
1	11	36	25	44	4	120
2	1	4	7	6	0	18
3	2	0	1	0	1	4
4	0	2	1	0	0	3
5	0	0	1	0	0	1
6+	0	1	2	0	0	3
M.D.	1	0	0	0	0	1
Total	16	48	40	56	5	165

Table F-25

Distribution of Front-Outboard Occupants in Rear-Damaged Passenger Cars by Seating System and Injury Variables

	≤ 5° Seatback Deflection						>5° Seatback Deflection					
	Head Restraint Configuration											
	M.D.	None	Up	Down	Integral	Total	M.D.	None	Up	Down	Integral	Total
Neck AIS												
0	1	3	3	34	18	59	1	7	13	16	16	53
1	0	8	6	26	25	65	2	7	23	39	30	101
2						0		1	1	1		3
3						0	1					1
4						0						
5						0						
6						0			1			1
Total	1	11	9	60	43	124	4	15	38	56	46	159
Neck Contacts												
Other				2	2	4	3		5	3		11
Front Seatback			3	4	6	13		3	13	10	10	36
Head Restraint			4	11	9	24	1		11	17	5	34
Belts				1		1						
Front Seat Cushion			1			1					1	1
Impact Force		7	6	21	20	54	2	4	18	29	26	79
Total	0	7	14	39	37	97	6	7	47	59	42	161
L. Back AIS												
0	1	11	7	48	39	106	3	15	33	43	35	129
1			1	11	4	16	1		3	12	11	27
2			1	1		2			1	1		2
3									1			1
4												
5												
6												
Total	1	11	9	60	43	124	4	15	38	56	46	159
L. Back Contacts												
Other									1		2	3
Head Restraint												
Front Seatback			1	7	1	9			3	8	5	16
Seat cushion												
Impact Force			2	10	3	15	1		4	11	7	23
Total	0	0	3	17	4	24	1	0	8	19	14	42

Table F-26

Distribution of Front-Outboard Occupants by Height, Driver's Head Restraint Configuration,and Neck/Lower Back AIS

	60"-65"			66"-71"			72"-77"			Other + MD			
Head Restraint Configuration	UP or Integral	Down	None	UP or Integral	Down	None	UP or Integral	Down	None	UP or Integral	Down	None	Total
Neck AIS													
0	36	24	11	57	40	18	22	18	6	24	18	12	286
1	40	27	18	60	44	13	13	16	2	26	14	4	277
3										1			1
4				1									1
5									1				1
6	2												2
Total	79	54	30	121	86	32	35	35	10	51	32	17	582
Lower Back AIS													
0	69	46	24	93	72	27	32	28	9	46	28	16	490
1	9	7	6	26	13	5	3	6	1	5	4		85
2	1	1		1	1			1				1	6
3				1									1
4													
5													
6													
Total	79	54	30	121	86	32	35	35	10	51	32	17	582

Table F-27

Distribution of Front-Seat Occupants by Overall AIS and Primary Damage Extent

Primary Damage Extent

Overall AIS	1	Col%	2		3-4		5-9		Total	
0	46	27.5	60	33.0	24	14.3	19	17.4	149	23.8
1	114	68.3	107	58.8	116	69.0	70	64.2	407	65.0
2+	7	4.2	15	8.2	28	16.7	20	18.3	70	11.2
Total	167		182		168		109		626	

Table F-28

Distribution of Rear-Seat Occupants by Overall AIS and Primary Damage Extent

Primary Damage Extent

Overall AIS	1	Col%	2		3-4		5-9		Total	
0	17	63.0	11	35.5	10	26.3	5	19.2	43	35.2
Row %	39.5		25.6		23.3		11.6			
1	10	37.0	20	64.5	23	60.5	17	65.4	70	57.4
	14.3		28.6		32.9		24.3			
2+	0		0		5	13.2	4	15.4	9	7.4
					55.6		44.4			
Total	27		31		38		26		122	

Table F-29

Distribution of Drivers by Seatback Deflection, Vehicle Damage Extent*, Head Restraint Configuration, and Overall AIS**

Head Restraint Configuration	Overall AIS	Seatback Deflection														
		Less than 5°					5°-10°					More than 10°				
		VDI Primary Damage Extent														
		1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
NONE	0	1				1									1	1
	1	3		4		7		1		1	2			3	2	5
	2+								1		1			1		1
	Total	4	0	4	0	8	0	1	1	1	3	0	0	4	3	7
DOWN	0	6	5		1	12			1	1	2		1		1	2
	1	16	8	3	2	29	2	4	7	2	15	7	5	6		18
	2+	1		1		2		1			1		2		1	3
	Total	23	13	4	3	43	2	5	8	3	18	7	8	6	2	23
UP	0								1		1				1	1
	1	2		1	1	4	1		1	1	3	1	3	4	2	10
	2+						1			4	5		2		3	5
	Total	2	0	1	1	4	2	0	2	5	9	1	5	4	6	16
INTEGRAL	0		5			5			1		1		2			2
	1	9	8	6	1	24	4	3	4		11	3	3	9	4	19
	2+			1		1		1	1		2		1	2		3
	Total	9	13	7	1	30	4	4	6	0	14	3	6	11	4	24
TOTAL	0	7	10		1	18			3	1	4		3		3	6
	1	30	16	14	4	64	7	8	12	4	31	11	11	22	8	52
	2+	1		2		3	1	2	2	4	9		5	3	4	12
	Total	38	26	16	5	85	8	10	17	9	94	11	19	25	15	70

*Recoded as follows: 1=1, 2=2, 3=3-4, 4=5-9.

**Recoded as follows: AIS 0 = 0, AIS 1 = 1, AIS 2-10 = 2+, Missing Data Excluded.

Table F-30

Distribution of Drivers by Seatback Deflection, Vehicle Damage Extent, Head Restraint Configuration, and Neck AIS

Head Restraint Configuration	Neck AIS	Seatback Deflection														
		Less than 5°					5°-10°					More than 10°				
		VDI Damage Extent														
		1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
NONE	0	1		1		2									2	2
	1	3		3		6		1	1	1	3			3	1	4
	2+													1		1
	Total	4	0	4	0	8	0	1	1	1	3	0	0	4	3	7
DOWN	0	8	10	2	1	21		1	2	1	4	1	1	2	2	6
	1	15	3	2	2	22	2	4	6	2	14	6	7	4	0	17
	2+															
	Total	23	13	4	3	43	2	5	8	3	18	7	8	6	2	23
UP	0								1	2	3		1	1	4	6
	1	2		1	1	4	2		1	2	5	1	4	3	2	10
	2+									1	1					
	Total	2	0	1	1	4	2	0	2	5	9	1	5	4	6	16
INTEGRAL	0	3	6	2		11	1		3		4	1	3	3	2	9
	1	6	7	5	1	19	3	4	3		10	2	3	8	2	15
	2+															
	Total	9	13	7	1	30	4	4	6	0	14	3	6	11	4	24
TOTAL	0	12	16	5	1	34	1	1	6	3	11	2	5	6	10	23
	1	26	10	11	4	51	7	9	11	5	32	9	14	18	5	46
	2+									1	1			1		1
	Total	38	26	16	5	86	8	10	17	9	44	11	19	25	15	70

Table F-31

Distribution of Right-Front Occupants by Seatback Deflection, Driver's Head Restraint Configuration, Vehicle Damage Extent, and Overall AIS

		Seatback Deflection														
		Less than 5°					5°-10°					More than 10°				
		VDI Damage Extent														
Head Restraint Configuration	Overall AIS	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
NONE	0															
	1		2	1	1	3							1	2	1	4
	2+									1	1				1	1
	Total	0	2	1	0	3	0	0	0	1	1	0	1	2	2	5
DOWN	0	4	1	1	1	7		2			2					
	1	2	3	3	1	9	1	1	2	1	5	2	1	2	1	6
	2+		1			1							1	1		2
	Total	6	5	4	2	17	1	3	2	1	7	2	2	3	1	8
UP	0			1		1								1		1
	1	1			2	3	1		1	2	4	2	2	1	3	8
	2+			1	1									1	1	2
	Total	1	0	2	2	5	1	0	1	2	4	2	2	3	4	11
INTEGRAL	0	1	3			4		1		1	2					
	1	2	3	3	1	9	1	1			2	1	1	2		4
	2+													2		2
	Total	3	6	3	1	13	1	2	0	1	4	1	1	4	0	6
TOTAL	0	5	4	2	1	12		3		1	4			1		1
	1	5	8	7	4	24	3	2	3	3	11	5	5	7	5	22
	2+		1	1		2				1	1		1	4	2	7
	Total	10	13	10	5	38	3	4	3	5	16	5	6	12	7	30

Table F-32

Distribution of Right-Front Occupants by Seatback Deflection, Vehicle Damage Extent, Driver's Head Restraint Configuration, and Neck AIS

Head Restraint Configuration	Neck AIS	Seatback Deflection Less than 5^o					5^o-10^o					More than 10^o				
		VDI Damage Extent 1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
NONE	0			1		1				1	1		1	1	2	4
	1	2				2								1		1
	2+															
	Total	2	0	1	0	3	0	0	0	1	1	0	1	2	2	5
DOWN	0	5	4	2	2	13		2	1	1	4	1		1		2
	1	1	1	2		4	1	1	1		3	1	1	2	1	5
	2+												1			1
	Total	6	5	4	2	17	1	3	2	1	7	2	2	3	1	8
UP	0	1		1	1	3			1	1	2			1	2	3
	1			1	1	2	1			1	2	2	2	1	2	7
	2+													1		1
	Total	1	0	2	2	5	1	0	1	2	4	2	2	3	4	11
INTEGRAL	0	1	4	1	1	7	1	1		1	3			1		1
	1	2	2	2		6		1			1	1	1	3		5
	2+															
	Total	3	6	3	1	13	1	2	0	1	4	1	1	4	0	6
TOTAL	0	7	8	5	4	24	1	3	2	4	10	1	1	4	4	10
	1	5	3	5	1	14	2	2	1	1	6	4	4	7	3	18
	2+												1	1		2
	Total	12	11	10	5	38	3	5	3	5	16	5	6	12	7	30

Table F-33

Distribution of Drivers and Right-Front Occupants with Integral Head Restraints by Seatback Deflection and Neck AIS, Grouped on Damage Severity

VDI Extents 1-2 (moderate)

Seatback Deflection

Neck AIS	$\le 5^{\circ}$		$>5^{\circ}$ $\le 10^{\circ}$		$>10^{\circ}$		Total	
		Col %						
0	14	45.2	0		4	36.4	18	41.9
1	17	54.8	1	100	7	63.6	25	58.1
2+	0		0		0		0	
Total	31		1		11		43	

VDI Extent 3-4 (Severe)

Neck AIS	$\le 5^{\circ}$		$>5^{\circ}$ $\le 10^{\circ}$		$>10^{\circ}$		Total	
0	4	33.3	4	57.1	6	30.0	14	35.9
1	8	66.7	3	42.9	14	70.0	25	64.1
2+	0		0		0		0	
Total	12		7		20		39	

Table F-34

Distribution of Drivers with No Head Restraint <u>or</u> Adjustable Head Restraint in the Down Position by Seatback Deflection and Neck AIS Grouped on Damage Severity

VDI Extent 1-2 (Moderate)

Seatback Deflection

		≤ 5°	Col %	>5° ≤ 10°		>10°		Total	
Neck AIS	0	19	47.5	1	12.5	2	13.3	22	34.9
	1	21	52.5	7	87.5	13	86.7	41	65.1
	2+	0		0		0		0	
	Total	40		8		15		63	

VDI Extent 3-4 (Severe)

		≤ 5°	Col %	>5° ≤ 10°		>10°		Total	
Neck AIS	0	4	36.4	3	23.1	6	40	13	33.3
	1	7	63.6	10	76.9	8	53.3	25	64.1
	2+	0		0		1	6.7	1	2.6
	Total	11		13		15		39	

REFERENCES

1. O'Day, et al., Statistical Inference from Multidisciplinary Accident Investigation, Highway Safety Research Institute, The University of Michigan, Ann Arbor, June 1973.

2. K.L. Campbell, Energy Basis for Collision Severity, SAE Paper 740565, 3rd International Conference on Occupant Protection, Troy, Michigan, July, 1974.

3. Accident Facts: 1974 Edition, National Safety Council, Chicago, 1974.

4. O'Neill, B. et al., "Automobile Head Restraints--Frequency of Neck Injury Claims in Relation to the Presence of Head Restraints," A.J.P.H., March, 1972.

5. Improvements Needed in Planning and Using Motor Vehicle Safety Research, B-164497(3), Report to the Committee on Commerce, U.S. Senate, by the Comptroller General of the United States, September, 1974.

6. States, J.D. and Balcerak, J.C., The Effectiveness of Head Restraints in Rear End Impacts, University of Rochester, School of Medicine, Rochester, N.Y., 1973.

7. McLean, A.J., Collection and Analysis of Collision Data for Determining the Effectiveness of Some Vehicle Systems, Highway Safety Research Center, University of North Carolina, 1973.

8. Vehicle Damage Scale for Traffic Accident Investigators, TAD Project Technical Bulletin, No. 1, Traffic Accident Data Project, National Safety Council, Chicago, 1971.

9. Collision Deformation Classification, SAE Recommended Practice, SAE Technical Report J224a, Revision of February, 1972.

10. Scott, R.E. and O'Day, J., A Sampling Program for Evaluation of the 1974 Restraint Systems, SAE Paper 750188, presented at the 1975 Automobile Engineering Congress and Exposition, February 24-28, 1975. Cobo Hall, Detroit.

11. Flora, J.D., Jr., "Ridits: A New Look at an Old Technique for the Analysis of Accident Injury Data," Hit-Lab Reports Vol. 5, No. 3, Nov., 1974.

12. O'Day, J. and Carroll, P.S. *The Use of Accident Data in the NHTSA Standards Enforcement Program*, Final Report, Report No. UM-HSRI-SA-74-4, Highway Safety Research Institute, The University of Michigan, Ann Arbor, Michigan, August, 1974.

13. Mathewson, J.H. and Severy, D.M., UCLA-ITTE "Automobile Impact Research," Police and Engineers Section, 42nd National Safety Congress, October, 1954.