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TRI-LEVEL ACCIDENT INVESTIGATION STUDY

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VOLUME I

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16. Abstract
Volume 1 is the final technical report of a program that describes accident investigation studies, which incorporate varying levels of accident detail, and accompanying analysis of accident data. In-depth multidisciplinary accident case studies are discussed, together with a description of the methodology used and the findings derived relative to human, vehicle and environmental factors. Special topics include small-car-large-car accident involvements, parked vehicle accidents, vehicle side impact performance, windshield retention failure, seat belt retractor mechanisms, multipurpose vehicles and hood-windshield penetration.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES CONTINUED

LIST OF FIGURES CONTINUED

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Auto Manufacturers

Ford Motor Company
General Motors Corporation
Chrysler Corporation
American Motors Corporation
Motor Vehicle Manufacturers Association
International Harvester
Wayne Corporation (School buses)

Medical

U of M Hospital Emergency Room
U of M Hospital Medical Records Office
U of M Department of Pathology
St. Josephs Mercy Hospital Medical Records Office
St. Josephs Mercy Hospital Pathology Department
Beyer Memorial Hospital
Fontana Taylor Ambulance Service

Police

Michigan State Police
Ann Arbor City Police Department
Washtenaw County Sheriff's Department

Highway

Washtenaw County Highway Department
Michigan Department of Highways
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Auto Repair

Sakstrup's Motor Service
Northside Towing
Frain's Lake Service
Dick's Union 76
H & H Service
Brewer's North Campus Gulf Service

Barko's Parking

Smith's Service Station

Miscellaneous

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Midwest Research Institute

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2.0 Summary

This report describes a program of accident investigation studies which were based on varying levels of accident detail and analysis of the resultant data. The program was sponsored by the Accident Investigation Division of the Research Institute, National Highway Traffic Safety Administration, Washington, D. C., and conducted by the Highway Safety Research Institute of the University of Michigan. This final report covers the second year of a Tri-Level Accident Investigation Study which was continued under contract No. DOT-HS-031-2-454 for the period July 1, 1972 - June 30, 1973. During this period William E. Scott was Chief of the Accident Investigation Division at NHSTA and Wayne Van Wagoner was the contract Technical Manager.

In the Tri-Level study concept various levels of detailed accident data, and related driver-vehicle information are incorporated within a broad program of field accident investigations conducted in a fixed geographic area with the objective of identifying and analyzing problems and topics relating to highway safety.

The final report consists of two volumes.

Volume I discusses the methodology used to examine accidents of special interest and the resultant levels of accident data obtained from these investigations. In-depth, multidisciplinary accident case studies are grouped and discussed with summaries of findings relative to the human, vehicle and environmental aspects of accidents. Special studies involving small car-large car involvements, parked vehicle accidents, side impact performance, windshield retention failure, seat belt retractor mechanisms, multi-purpose vehicles and hood-windshield penetration are also included in this volume.

Volume II contains summaries of 50 Level III, multidisciplinary case studies which were completed and submitted to NHTSA during the course of the program. All reports are available for public viewing and/or sale in the Technical Reference Division, Room 5108, National Highway Traffic Safety Administration, 400 Seventh Street, S. W., Washington, D. C. 20590.

3.0 Introduction

In the Tri-Level Accident Investigation Study Program accidents are investigated in varying degree of accident detail, and the assembled data analyzed in order to better understand the accident process, i.e. to determine accident and injury causation. When functional problems in highway safety are identified, effective countermeasures are recommended.

The relatively limited number* of in-depth case studies completed, and the non-random selection methods used to obtain these cases,have posed some limitations on interpretation of the data relative to the general accident population. Police reported (mass) accident data within the study region represent a census, which permits an assessment of frequency of accident by type, severity, etc. The level of detail is not great, but such data do serve as a baseline, or foundation, for more detailed analyses of those specific problems posed or identified during the in-depth multidisciplinary investigations.

In multidisciplinary, in-depth case studies, the entire spectrum of a crash is examined -- human, vehicle, and environmental in each phase of the collision (pre-crash, crash, and post-crash). Even though the total sample of these accidents is relatively small, the collection of data is useful in studying causes and effects as they relate to accidents. Over 800 different data variables (items of information) are collected in multidisciplinary accident case studies. They are used in numerous topical subject areas for comparative evaluation, and indication of trends between or among variables. This report includes some of these studies, as well as a general description of all accident investigations conducted during the year plus findings, both evident and inferred, derived therefrom.

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* A total of 50 in-depth multidisciplinary accident case studies were completed within the one program.

4.0 Methodology

Methodology employed in the various HSRI tri-level accident investigation efforts differs in terms of timeliness and extent of the accident investigation. As the name implies, various levels of accident information are combined, each acquired with a different approach, so that collectively they may be examined to determine frequency, magnitude, detail and special areas of unique interest relative to problems of highway safety. All data are obtained within Washtenaw County, Michigan, which serves as the geographic area of the tri-level study.

It was initially hoped that from the data obtained at each level, all within a defined geographical area, one could draw inferences regarding the general accident population of the United States. However, any inferences are limited because -- (1) completion of a full multidisciplinary accident investigation case study eliminates random selection because some cases are dropped if complete information cannot be obtained (for example, when one driver refuses to be interviewed and his actions and state of mind are important to fully understanding the case), and (2) the provincial biases inherent in examining accidents in a particular geographic area which contains only 0.1% of the U. S. population. In spite of these limitations the combination of Level I, II, and III data presented here are of value in understanding the accident process; and several analyses using various levels of data will be presented.

The multidisciplinary accident investigation case studies, when combined with similar case studies from other areas of the country, form a sizable data base which was examined under another HSRI study. The Washtenaw County accident data file grew largely from investigations sponsored by both the National Highway Traffic Safety Administration and the Motor Vehicle Manufacturers Association. Within that data this study represents a subset of tow-away crashes involving new American made cars.

The program tri-level efforts consist of police reported data (Level I), special bi-level accident investigations providing accident and injury information for certain accidents in greater detail than that found in the police reported investigations (Level II), and multidisciplinary in-depth investigations (Level III) conducted by a team of specialists representing different professional disciplines.

The Level I (police reported) data have been acquired since 1965 and built into a digital file for Washtenaw County, Michigan, under a program sponsored by the Motor Vehicle Manufacturers Association. Copies of all police accident reports are collected daily from the major police agencies (bi-weekly from small villages) These reports are analyzed, coded, keypunched, and then incorporated into the Washtenaw County Accident File. These reports are maintained in the active file for five years, after which they are retired to the archives for longer term trend analysis.

Level II accident investigations cover two categories of accidents. The first category covers current model domestic vehicles which were sufficiently damaged to require towing from the scene, and in which there were minor or no injuries*. This provides an assessment of the performance of new vehicles relative to injury causation. In each case a GM Collision Performance and Injury Report (Long Form) is completed, vehicle occupants are interviewed and asked the nature and extent of injuries incurred and what vehicle interior surfaces they contacted, and the accident vehicle, accident site and roadway environment are photographed in color. Each morning the previous day police accident reports are screened for selection and assigned to field accident investigators who immediately contact occupants to determine the nature, extent, and cause of injury. Concurrently, other investigators examine the vehicles. Field investigators file a packaged accident investigation report which includes their own edited photography and completed forms.

* Washtenaw County Accident Investigations Program, R. Darby, Principle Investigator, sponsored by the Motor Vehicle Manufacturers Association.

The other category of Level II accident investigations covers accidents involving current model domestic vehicles where there were serious or fatal injuries*. These investigations have been conducted for over ten years in Washtenaw County, and the majority of cases are initiated by reviewing police reports of the previous day's accidents but some are initiated on-scene as the result of a police alert. Police notification usually is limited to fatal accidents, and may come at most any time. As in the first category the final reports include a completed GM Collision Performance and Injury Report and vehicle and scene photography, plus photographs of occupant injuries when possible. They also contain a summary report describing primary causal factors, vehicle and occupant kinematics, a medical description of injuries sustained by the occupants, and an accident schematic diagram.

Level III investigations are conducted by a multidisciplinary team consisting of a mechanical engineer, a psychologist, a traffic and highway engineer, an accident reconstructionist and a medical doctor-pathologist. Also included are experts in law, toxicology and metallurgy, as required. This approach is used for in-depth and detailed case accident findings concerning selected accidents. Accident case selection is based on criteria established by the NHTSA**, sponsors of this portion of the program. These selection criteria limit Level III investigations to accidents involving at least one vehicle within the past three model years, trucks (within the previous ten model years), recreation vehicles, motorcycles, bicyclists, and pedestrians. The completed formal case studies cover the pre-crash, crash and post-crash phases and all findings relevant to the human, vehicle and environmental aspects of the crash.

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* Washtenaw County Accident Clinical Case Investigations, Donald F. Huelke, Principle Investigator, supported by the Motor Vehicle Manufacturers Association.

** As specified within the contract work statement for the Tri-Level Accident Investigation Study.

Figure 4.0-1 HSRI accident research personnel and vehicles, with the University of Michigan Highway Safety Research Institute as background.

Accident alert comes from a direct police call* or monitoring of police radio frequencies**. In general, Level III accident investigations begin at the site of the accident. Vehicle occupants and witnesses are interviewed on-scene when possible and vehicle and environment crash evidence noted and preserved. A minimum of two multidisciplinary team members respond to the accident. A detailed procedure for on-scene investigations is not possible because each accident sufficiently differs from the previous accident to require some variation in approach. However, the following general guidelines are followed by accident team personnel.

1. Each investigator's approach toward obtaining information when on-scene tends to complement the other's. For example, when one investigator is involved with on-scene vehicle data and photography, the other interviews drivers, occupants, or witnesses for human data needed for reconstructing the accident in detail in conjunction with police reports.

2. One investigator accompanies the injured to the hospital, follows the injured through the Emergency Room process, and obtains injury information, and human factors data when possible. Also, when possible, nearest of kin, relatives, and friends who enter the hospital are queried for information relative to the injured. This is most effective when done in the company of the police officer responsible for the case.

3. The second on-scene investigator remains at the accident site through the clean-up phase until the various emergency personnel involved have departed. A review of all events and evidence involved in the accident at this time, under a more relaxed and contemplative atomsphere, can provide greater understanding of the overall accident and the best approach to take from that point on.***

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* A special red telephone used only for incoming police alerts exists within HSRI and the University Security Office which is manned 24 hours a day. Security Office personnel answer incoming calls during the night and on weekends and forward the information to investigators on a "call list".

** Monitor receivers are installed in accident investigation vehicles as well as within HSRI.

*** HSRI accident vehicles are specially equipped for interviewing subjects and completing case paperwork in the field.

4. Independent follow-up investigations for more detailed (human, vehicle, and environmental) data are accomplished as soon after the accident event as possible.
5. A preliminary case debriefing is accomplished with all involved individuals at the earliest possible convenient time after the accident.
6. The more complete and detailed case study debriefing is attempted only when all basic case data have been acquired.

Thus, the three levels of accident data are approached differently, ranging from the daily collection of routine police accident reports to an on-scene, specialist accident team investigation.

5.0 Accident Data

The finite geographic study area for this program is Washtenaw County, Michigan. Admittedly a single county area introduces biases into the accident data, but the area does include both rural and urban features with a broad representation of differing roadways and population characteristics.

Washtenaw County has 711 square miles of urban and rural land allocated to all types of land use, 235,000 population, and 2,000 roadway miles, of which 71 miles are freeways. Annual accident statistics include about 65 fatal, 2,500 injury and 6,000 property damage accidents. Two large universities and two colleges, plus their associated research and advanced learning institutions, result in a disproportionate number of young drivers in the total driver population.

The dominant Ann Arbor-Ypsilanti urban area has 780 miles of roadway as follows:

	Class	Mileage	% of Total
Principal	(Interstate Freeways (Other Freeways (Other Principal Arterials	104	13%
Minor Arterial		84	11%
Collectors		77	10%
Local Streets		515	66%
		730	100%

The major urban Standard Metropolitan Statistical Area is coterminus with the boundaries of Washtenaw County. Major institutions within this urban area draw traffic from all over the State of Michigan and the United States.

There are more than 140 signalized intersections within the tri-level study area. Less than 5% of these are semi or fully actuated. Standards used for establishing traffic controls follow as closely as possible the specifications and guidelines of the Michigan Manual for Uniform Traffic Control Devices, and as amended to date, the New National Manual for Uniform Traffic Control Devices.

The levels of accident data described in the previous section are the basis for analysis and correction of local highway safety problems. These data are contained in two basic computer files, the Washtenaw County Accident File, and the Collision Performance Injury Report (CPIR) File, also called the Long Form File.

The Washtenaw County Accident File consists only of mass accident information, classed as Level I data. Periodic file "builds" are completed once a group of individual accident cases have been analyzed, coded and key punched. Individual "hard copy" reports of each accident are also filed for reference, and for follow-up of individual accidents of interest. A recent updating to this file has increased the total number of accident cases to 33,453. As many as 177 discreet variables may be entered for a given accident. The active file contains five years of county accident experience, and use of the data is increasing.

The CPIR file includes three interrelated sub-files. These are:

1. Vehicle File - contains a single and complete entry for each vehicle in an accident case study.
2. Occupant File - contains a complete individual record of each vehicle occupant in an accident case study.
3. Injury File - contains a complete single record of each person injured in an accident case study.

This file includes all multidisciplinary accident investigation case studies completed by HSRI, as well as Level II accident investigations described in Section 4.0. Under a separate

NHTSA contract*, all similar multidisciplinary accident investigation team accident case studies, conducted by other multidisciplinary accident investigation teams around the country, are being edited and built into the CPIR file.

In addition to the Washtenaw County Accident File and Collision Performance and Injury Report File (CPIR), HSRI has other computer stored, easily assessible data files available for developing driver, vehicle, and accident profiles in the tri-level study area. These files are tabulated in Table 5-1 to illustrate their value and utility in supplementing accident data peculiar to Washtenaw County.

Three classes of data are available. Each contains information which can be used to support a wide variety of analysis topics.

TABLE 5-1 HSRI DATA FILES

<u>Statewide</u>

Michigan Fatal Accidents

<u>Oakland County</u>

Vehicle Registration Sample File
Police Reported Traffic Accidents
Level III Clinical Investigations

<u>Washtenaw County</u>

Driver Registration Sample File
Vehicle Registration Sample File

The Washtenaw County driver sample file contains extensive information on the past driving history of this population. The data can provide a profile of the number of arrests, accidents, convictions, and violations for "typical" drivers.

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* DOT contract No. DOT-HS-031-1-037, Multidisciplinary Accident Investigation Report Automation.

Vehicle registration files provide a similar profile for vehicles. Information in these files include:

(1) Model Year

(2) Vehicle Make

(3) Body Style

(4) V.I.N.

(5) Weight

(6) Number of Cylinders

(7) Engine C.I.D.

(8) Engine H.P.

In addition to accident and highway safety data that is peculiar to Washtenaw County and Michigan, HSRI maintains a large volume of accident data representing other areas of the United States. Some of these are:

(1) Denver County, Colorado

(2) An eight county area around Buffalo, New York

(3) King County, Washington (Seattle)

(4) Dade County, Florida (Miami)

(5) Sample of all Texas Accidents

(6) Bexar County, Texas

6.0 Multidisciplinary Case Studies

A total of 50 in-depth, multidisciplinary case studies were completed this past year. These included most all of the primary accident orientations (head-on, side impact, etc.) and such vehicle types as school buses, trucks, multipurpose vehicles, motor homes, motorcycles, bicyclists, as well as pedestrians.

Table 6.0-1 is a tabulation of these case studies by case number, model year, type, body style and model of vehicle, speed, vehicle damage index*, and accident configuration. It is presented here as a descriptive summary index of all Level III cases.

The relevance of these Level III accident case study investigations to various motor vehicle safety standards is tabulated in Table 6.0-2. These standards, which resulted from the National Traffic and Motor Vehicle Safety Act of 1966, detail various vehicle performance specifications or requirements, to which vehicles must conform, when manufactured.

Noteworthy is the many instances (25) in which Motor Vehicle Program Standard #201, Occupant Protection in Interior Impact, has been cited. This standard specifies vehicle interior performance in a crash so as to minimize injury to occupants. Other frequently cited standards are MVPS #203, Steering Controls and MVPS #205, Glazing Materials which also relate to vehicle interiors, and their propensity towards injury production.

The surprisingly frequent citing of MVPS #301, Fuel Tanks, Fuel Filler Pipes, and Tank Connections resulted primarily from the many accidents in which fuel leakage was noted. In two accidents (AA335 and AA338), fire completely destroyed the vehicles, but with no resulting injury to occupants.

In order to evaluate these multidisciplinary case studies completed during the year with similar investigative efforts nationwide, the CPIR data file was searched relative to a number

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* Vehicle Deformation Index (VDI) in accordance with recommended practice of vehicle deformation classification as set forth in SAE Technical Report J224a.

Table 6.0-1. HSRI Multidisciplinary Accident Investigation Case Studies

Case No	Model Year	Make	Model	Body Type	Speed at Impact	VDI	Accident Configuration
301	70	Jeep	Mail Delivery Vehicle		25	03-RYEW-2 06-EDAN-1	Intersection
	63	Plymouth	Valiant	Conv.	22	11-FYEW-2	
302	70	Ford	Maverick	2 door	13	02-RFEW-3 03-RBMN-1	Intersection
	63	Pontiac	Bonneville	2 door	34	11-FYEW-1 09-LPMW-1	
303	71	Plymouth	Satelite	Sta. Wagon	60	01-FDEW-4	Head-on
	68	Chevrolet	Impala	Sta. Wagon	50	11-FLAW-5 00-TDAO-3	
304	71	Ford	Ranch Wagon	Sta. Wagon	0	02-RFEW-2	Intersection
	69	Fiat	Sport 850	Conv.	35	09-LPAW-3 04-RBMS-1	
305	70	Volvo	164	4 door	50	01-FREW-5	Fixed Object, Head-on
306	72	Pontiac	Grand Prix	2 door	70	01-RDAW-9 08-LBEW-1	Head-on
	68	Chrysler	Newport Custom	4 door	60	11-FDAW-6	
Special			School Bus				Rollover
307		Harley Davidson	Super Glide	Motorcycle			Rear-end
	69	Pontiac	Catalina	Sta. Wagon		07-RCEN-1	
308	72	GMC	Tram Corp. Titan I	Ambulance Van	2D	02-RFEW-3	Intersection
	66	Cadillac	deVille	Conv.	40	10-LPAW-3 07-LPAN-1	
312	70	Pontiac	Firebird	2 door	40	12-FREW-3	Rear-end
	68	Plymouth	Valiant	4 door	-5	06-BLEW-5	
314	71	Ford	Mustang	2 door	30	12-FYEW-2	Head-on
	64	Mercury	Comet	2 door	20	12-FYEW-1	

Table 6.-01 cont.

VW Case No.	Model Year	Make	Model	Body Type	Speed at Impact	VDI	Accident Configuration
315	70	Chevrolet	Nova	2 door	3	12-FLEN-0	Pedestrian
316	70	Internat. Harvester	Loadstar 1600	School Bus	20	10-LFEW-2 00-LDHW-1	Intersection, rollover, fixed object
	63	Dodge	Dart	2 door	35	02-RDAW-6 00-TPGW-3	
318	71	Chevrolet	Belair	4 door	30	10-LEEW-2	Intersection
	68	Plymouth	Satelite	2 door	25	02-FDEW-1	
319	71	Chevrolet	Camaro	2 door	50	10-LYEW-2	Intersection
	72	AMC	Hornet	2 door	35	02-FDEW-2	
320	71	Plymouth	Duster	2 door	65	00-TPEW-3	Rollover
321	72	Mercury	Monterey Custom	4 door	20	12-FCEN-2 11-FLES-1	Fixed object, head-on
322	71	Ford	Mustang	2 door	0	06-BDEW01	Intersection
	62	Ford	Falcon	2 door	15	12-FDEW-1	
323	70	Mercury	Monterey	4 door	50	12-FDEW-4	Head-on
	67	Chevrolet	Concours	Sta. Wagon	50	12-FDEW-4	
324	67	Pontiac	Firebird	2 door	27	12-FLEN-0	Pedestrian
325	72	Ford	Capri	2 dr.	15	12-FCEN-2	Fixed object, head-on
326	65	GMC	1700	Tractor	30	10-LYAW-1	Run off road
327	72	Ford	Maverick	2 door	20	10-LDAW-2 00-RDEO-1	Car-train intersection
328	72	Ford	Maverick	2 door	75	00-XDAO-4	Rollover
329	64	Plymouth	Valiant	2 door	25	12-FRMN-1	Pedestrian

Table 6.0-1. contd.

[illegible]	[illegible]	Make	Model	Body Type	Speed at Impact	VDI	Accident Configuration
330	71	Cadillac	Coupe de Ville	2 door	55	12-FREA-3	Rear-end
	52	GMC	M135 6x6	Army truck	32	06-BLLW-2	
331	70	Chevrolet	Nova	2 door	35	03-RFEW-3	Fixed object
332	72	Ford	Bronco	2 door	60	00-XDAO-3	Rollover
333	73	Chevrolet	Vega	Sta. Wagon	60	06-BRAW-4 12-RDMS-1	Run-off road
334	71	Pontiac	Tempest	2 door	10	12-RFEN-2 06-LDMS-1 11-FLMN-1	Run-off road, fixed objects
335	70	Ford	LTD	2 door	15	06-BDEW-4	Rear-end
	66	Chevrolet	Chevelle	2 door	45	12-FDEW-2	
336	71	Ford	Galaxie	2 door		07-BYEW-5	Rear-end
	66	Pontiac	Ventura	2 door		12-FDEW-1 12-VDLW-1	
337	71	Ford		School Bus	10	12-FDEW-1	Head-on
	66	Pontiac	Tempest	2 door	20	12-FDEW-2	
338	73	Swinger	28' Statesman	Motor home	60	00-RDMO-1	Rollover
339	69	Chevrolet	450	Stake Truck	3	12-FRMN-0	Pedestrian
340	72	Buick	LeSabre	4 door	5	10-LFMW-2	Intersection
	70	Ford	Maverick	2 door	10	01-FZEW-2	
341	72•	Buick	Electra 225	4 door	5	12-FRMN-0	Pedestrian
342	71	Chevrolet	Vega	Sta. Wagon	10	12-FDEN-1	Intersection
	71	Ford	Maverick	2 door	0	09-LYMW-2	
343	72	Plymouth	Duster	2 door	30	09-LDAW-3 03-RFEN-2	Car-train intersection

Table 6.-01 contd.

	Year	Make	Model	Body Type	Speed at Impact	VDI	Accident Configuration
344	71	Ford	Pinto	2 door	30	03-UBLN-1 06-LBMW-1	Run-off road
345	72	AMC	Gremlin	2 door	35	12-FYEW-1 12-RYMS-1	Run-off road, fixed objects
346	73	Oldsmobile	Omega	2 door	25	12-FYEW-3 09-LRMW-1	Intersection
	66	Ford		2 door	15	01-FREW-4	
347	72	Suzuki	750 GT	Motorcycle	20		Head-on
	67	Ford	Custom	2 door	20	11-LFES-1	
	71	Buick	Skylark	2 door	5	07-LBMW-1	
348	73	Kawasaki	500	Motorcycle	40		Intersection
	72	Inter-national	Careostar 1710	Truck	5	09-LBMW-1	
349	72	Suzuki	350	Motorcycle	30		Run-off road
350	73	Chevrolet	Nova	2 door	25	12-FDEW-3	Head-on
	68	Chevrolet	Chevelle	q door	25	12-FDEW-3	
351	71	Dodge	Sportsman	Van	35	02-RDMW-0	Pedestrian
352	70	Ford	Mustang	2 door	25	12-FDEW-2	Rear-end
	71	Mercury	Cougar	2 door	0	06-BDEW-1	
	66	Buick	Skylark	Conv.	0	12-FDEW-1 06-BDEW-2	
353	71	Honda	175	Motorcycle	25		Head-on
	71	Chevrolet	Vega	2 door	5	01-FCEN-2	
354	68	Ford	F-700	Tractor	-5	06-BPHN-9	Rear-end
	72	Diamond Reo	C-11664DB	Tractor	10	to trailer 02-RRMN-1	
355	73	Pontiac	Grand Am	2 door	60	11-FCEN-3 03-RPAW-3	Fixed object head-on

TABLE 6.0-2

Motor Vehicle Safety Standards

Standard No.	Standard Title	Times Referred
101	Control Location, Identification & Illumination	1
103	Windshield Defrosting & Defogging Systems	1
105	Hydraulic Brake Systems	1
108	Lamps, Relfective Devices & Associated Equipment	1
111	Rearview Mirrors	1
122	Motorcycle Brake Systems	1
201	Occupant Protection in Interior Impact	25
202	Head Restraints	7
203	Impact Protection for Driver from Steering Control System	12
204	Steering Control Rearward Displacement	3
205	Glazing Materials	10
206	Door Locks and Door Retention Components	9
207	Anchorage of Seats	7
208	Accoupant Crash Protection	6
209	Seat Belt Assemblies	2
212	Windshield Mounting	7
213	Child Seating Systems	1
214	Side Door Strength	8
216	Roof Crush Resistance	4
301	Fuel Tanks, Fuel Filler Pipes, Tank Connections	12
302	Flammability of Interior Materials	2

of key accident variables. Figure 6.0-1 compares urban/rural accidents with the complete CPIR file, and shows good agreement with the percentage of urban/rural accident cases initiated by other multidisciplinary teams about the country. Figures 6.0-2, 6.0-3, 6.0-4, 6.0-5, 6.0-6 and 6.0-7 similarly compare rollover accidents, vehicle involvement by manufacturer, limited access highway accidents, accident locality, accidents by hour of the day and accidents by day of the week. Overall, HSRI accident case studies as shown matched similar data in the CPIR file.

The summarizing of all accident case studies by matrix cell factors proved interesting. This matrix is utilized to more conveniently and accurately categorize causal factors, findings, conclusions and recommendations offered by researchers and is included in each individual accident case study, with an appropriate listing of matrix cell factors as they relate to the accident being reported.

Each directly relevant cell factor consideration is numerically grouped by the following matrix designation.

	Pre-Crash	Crash	Post-Crash
Human	1	2	3
Vehicle	4	5	6
Environmental	7	8	9

A citing of cell factor one (1) in a case study, for example, would pertain to some relevant human factor consideration prior to the crash, which contributed in some manner to the actual occurrence of the collision. Noting an improper evasive action

FIGURE 6.0-1
Percentage of Urban/Rural Accidents

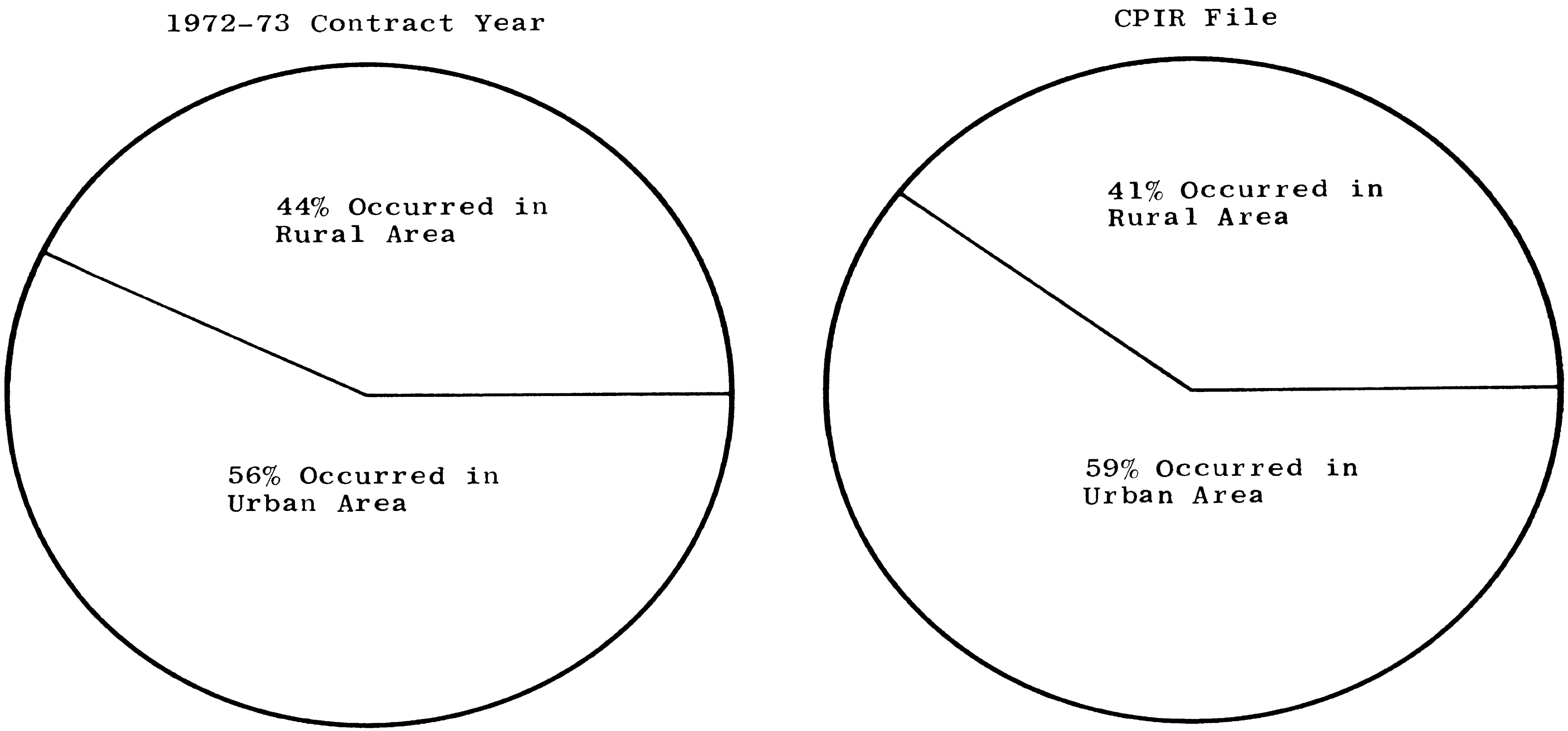


FIGURE 6.0-2
Percentage of Rollover Accidents

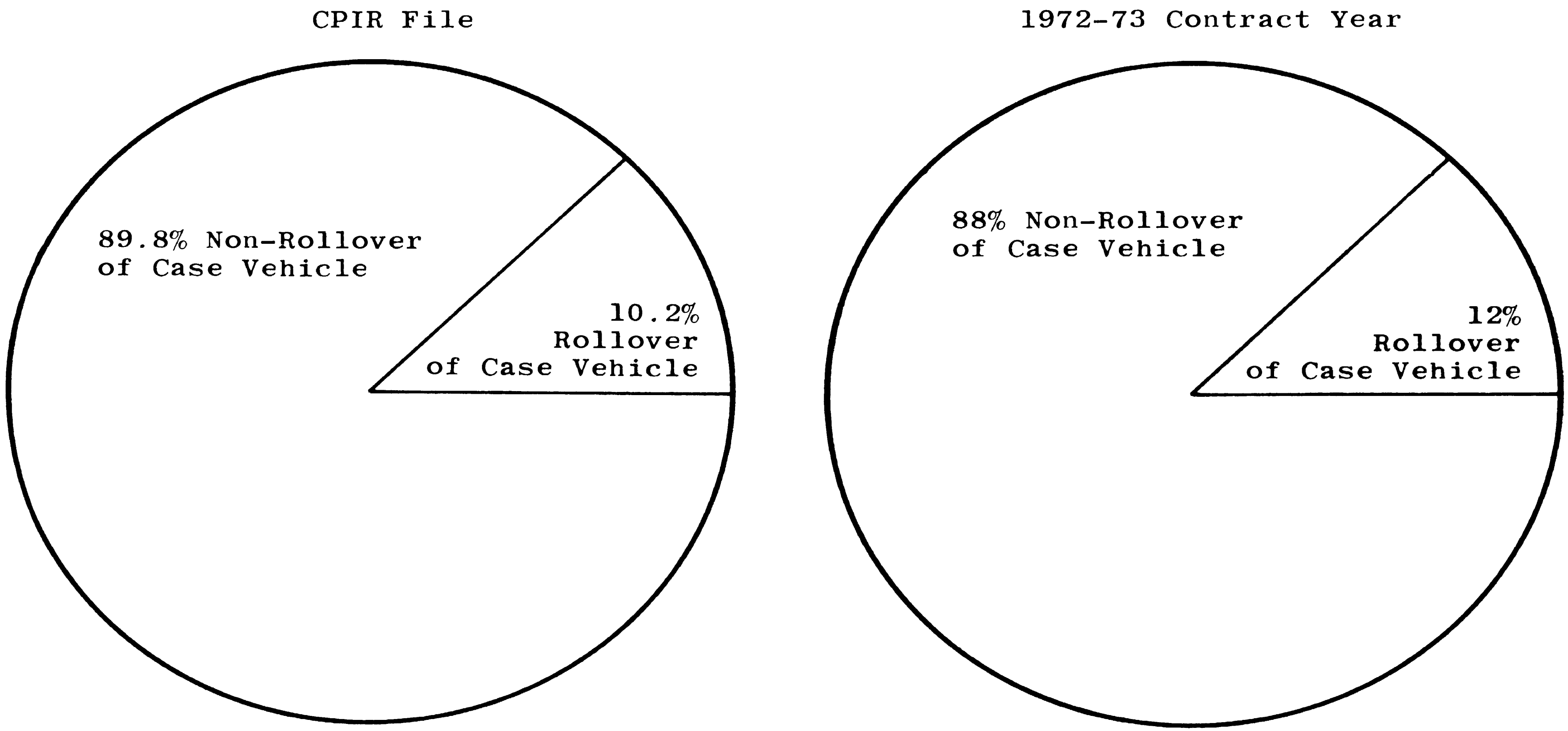


FIGURE 6.0-3
Passenger Car Involvement by Manufacturer

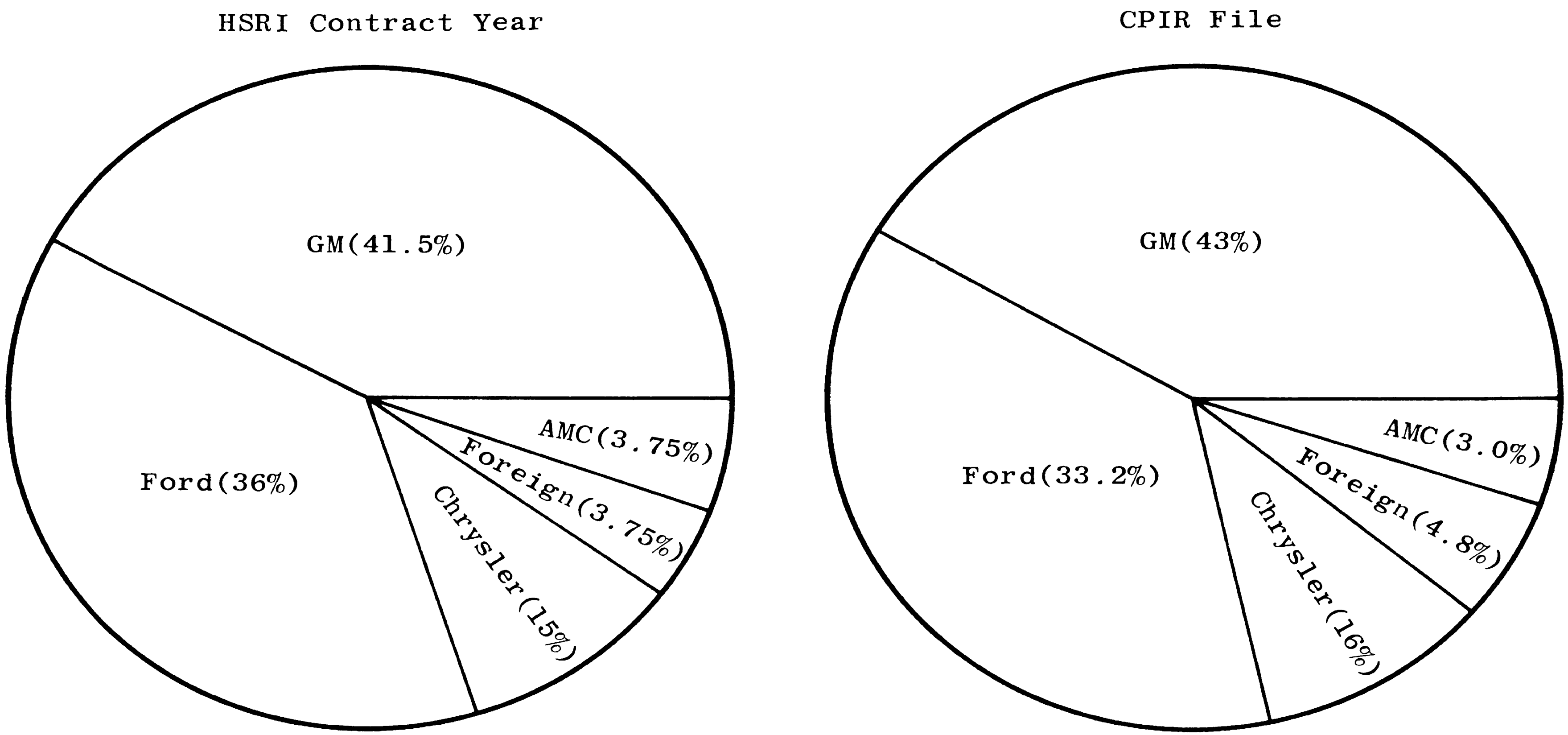


FIGURE 6.0-4

Percentage of Limited Access Highway Accidents

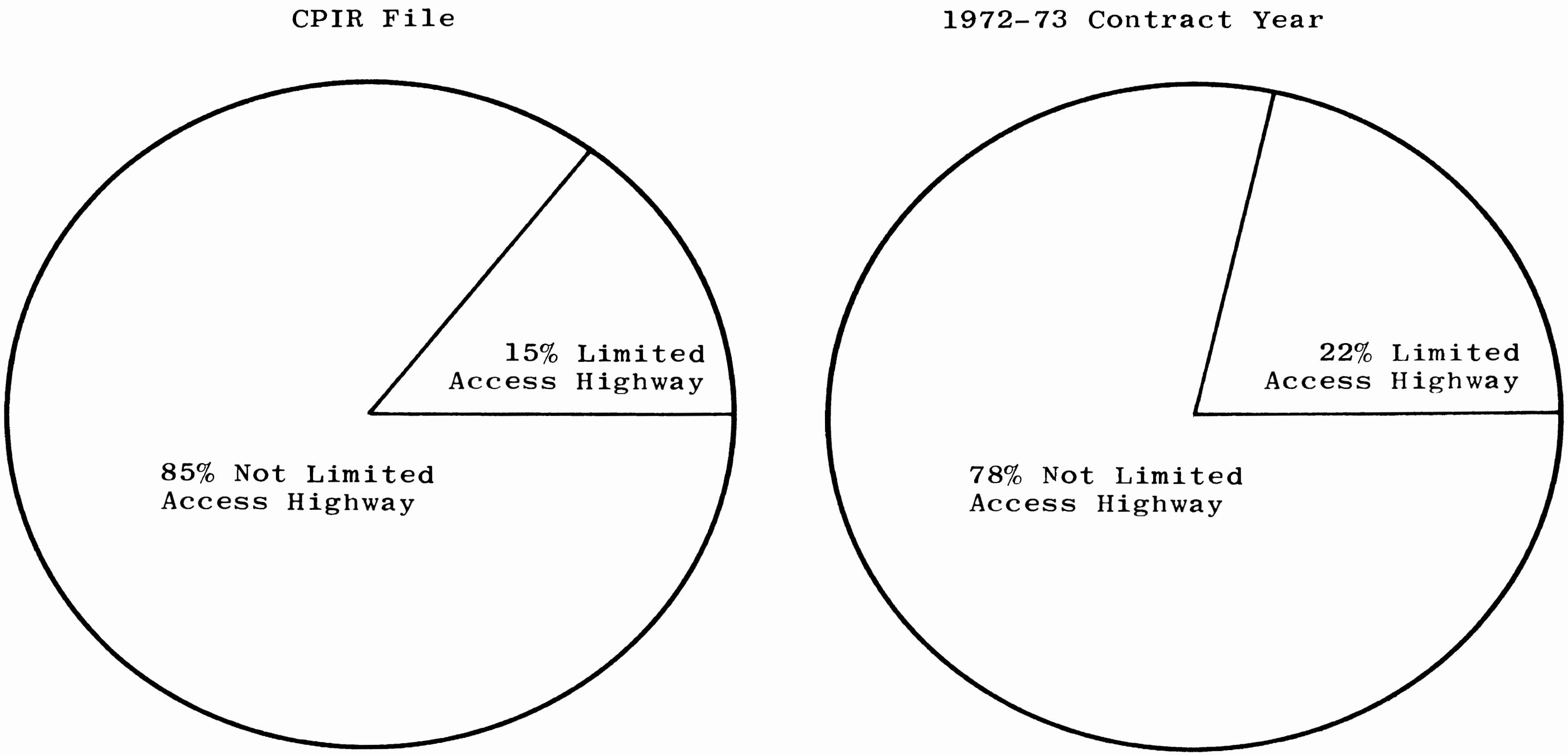


FIGURE 6.0-5
Accident Locality

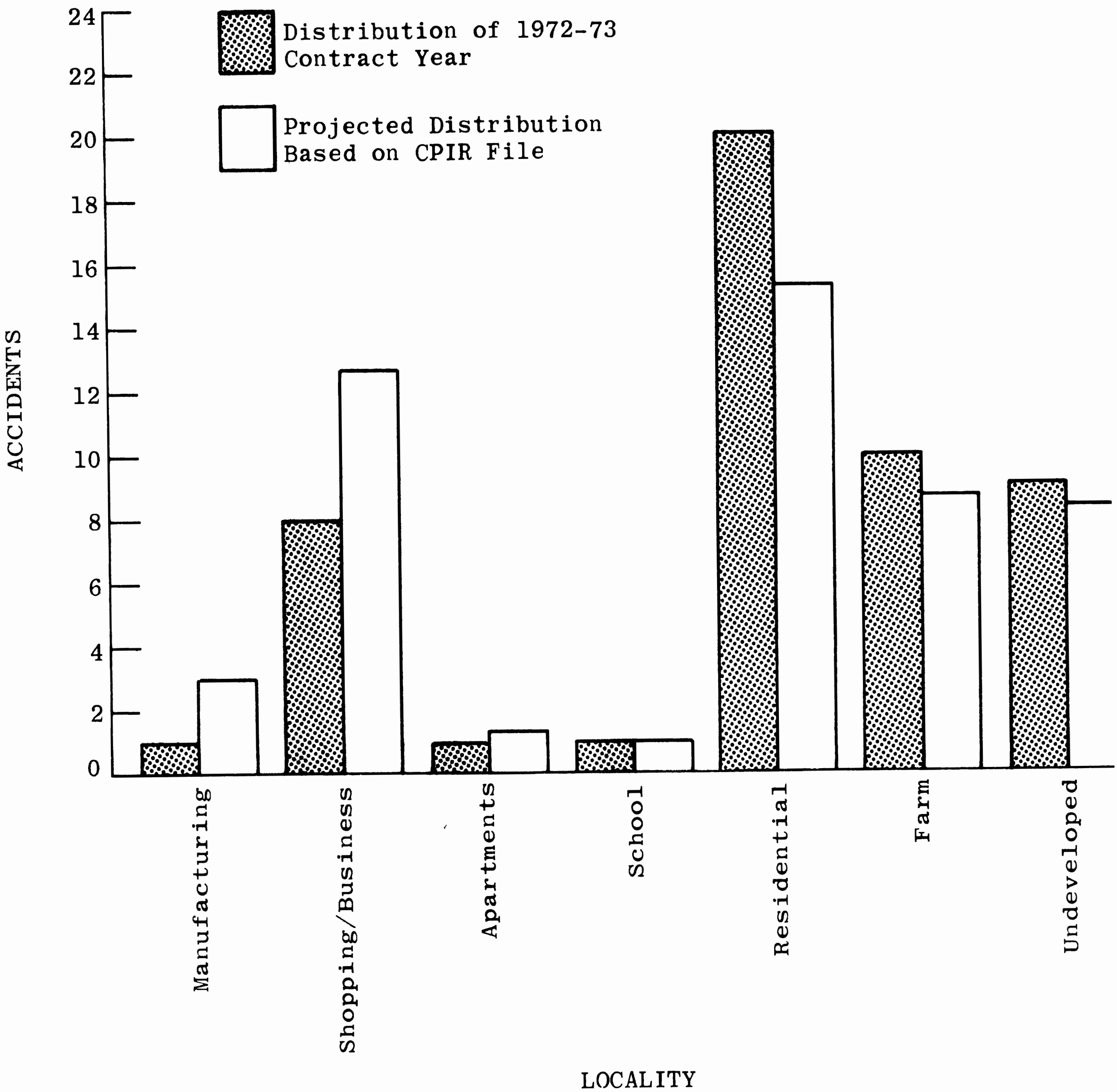


FIGURE 6.0-6
Number of Accidents by Hour of Day

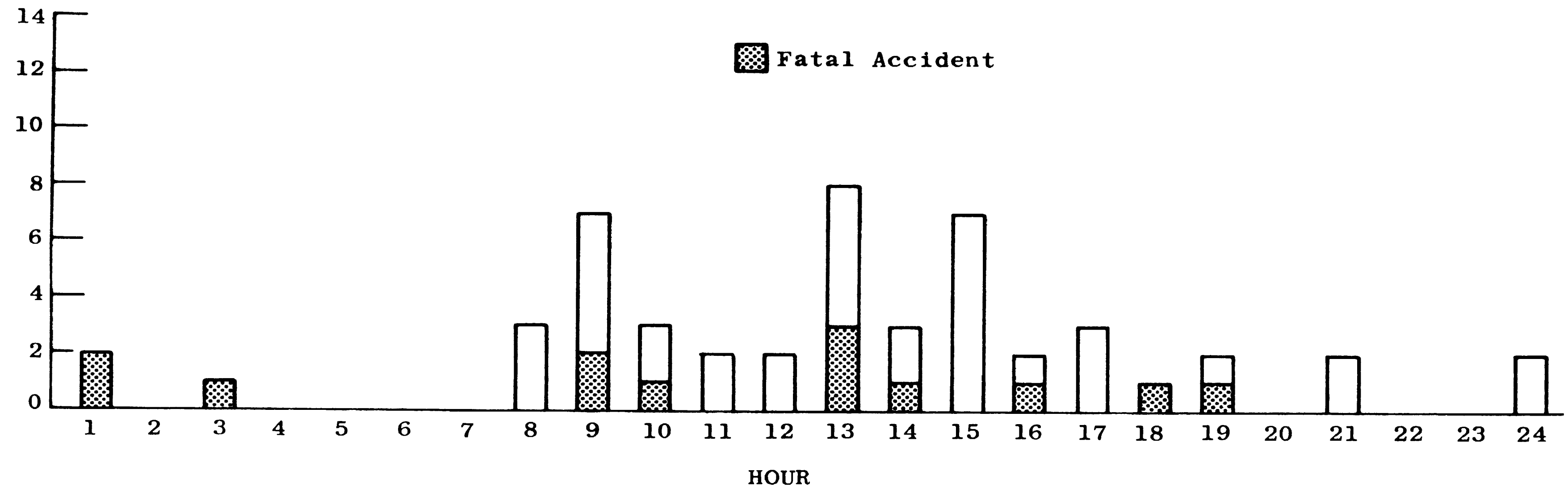
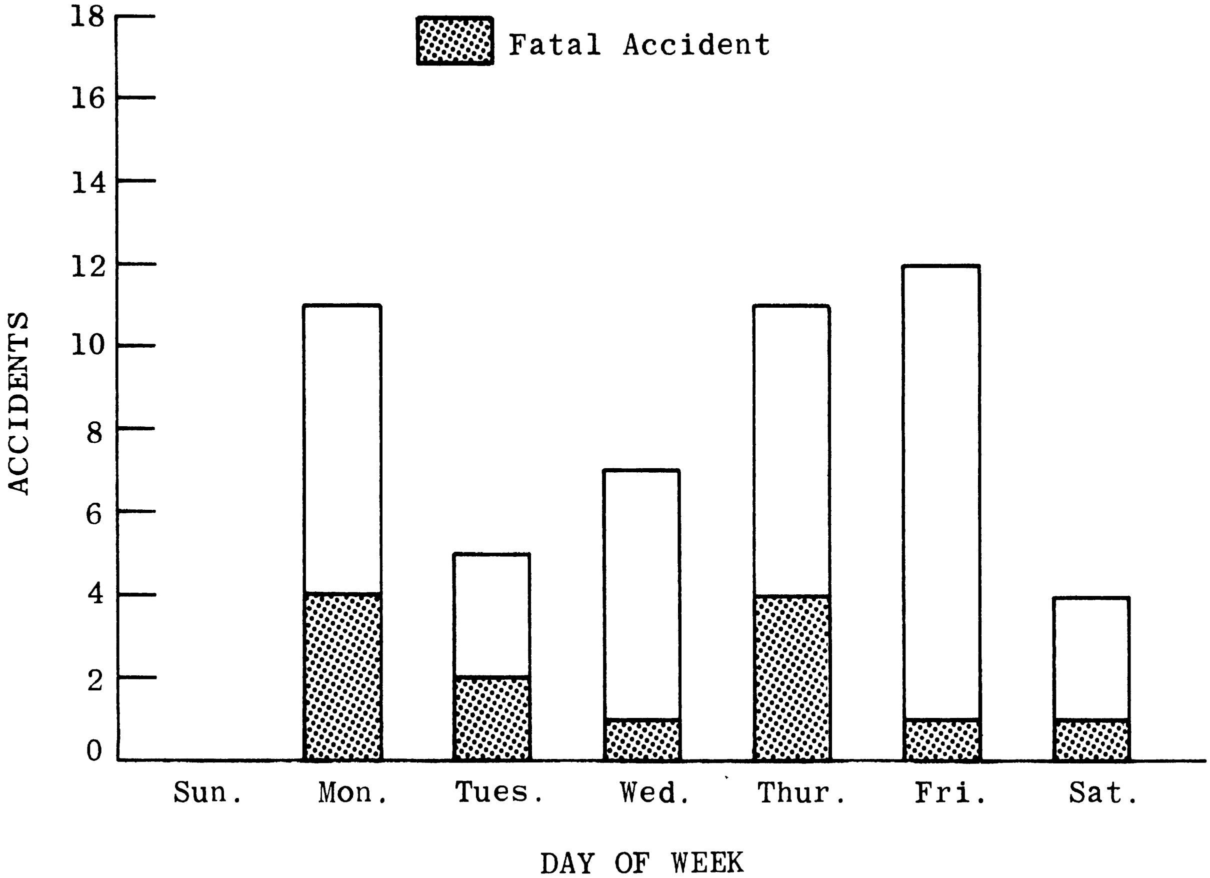


FIGURE 6.0-7
Number of Accidents by Day of Week



on the part of a driver would, for example, be classified within cell factor one (1). A summing of these cell factors and their grouping according to the matrix organization is presented in Table 6.0-8. A plus (+) indicates a positive factor or some action, event, or condition which tended to amerliorate the effects of the crash, such as prompt emergency medical response. A minus (-) indicates a negative factor, or damage or injury severity increasing factor, such as driver impairment from alcohol consumption. This table indicates the predominance of negative human pre-crash factors, emphasizing that the vulnerable element in the accident process is the human factor.

In Table 6.0-9 a tabulation of these same matrix cell factors is presented so as to illustrate their relationship to individual accident case studies.

Table 6.0-10 is a tabulation of individual multidisciplinary investigation accident case studies summarizing the environmental factors. The majority of accidents occurred under clear, dry, lighted roadway conditions.

The 50 case studies involved 79 vehicles, 128 occupants, and 6 pedestrian accidents which involved 3 adult and 3 child pedestrians.

The mean age of the driver population was 33 (32, male, 34 female). The median age was 36 and the most frequent age was 22, indicating the higher accident involvement of young drivers and the relatively high proportion of young drivers in this university community sample.

Twenty two of the 128 occupants were lap belted (17.6%). None of the occupants wore the upper torso belt. One infant in a child safety seat was not injured.

Of the 78 drivers, 34 (44%) were primarily responsible for the accident, 20 (26%) contributed to the accident, and 24 (26%) were not at fault.

Table 6.0-11 illustrates the distribution of driver responsibility and sex. Young drivers were more responsible for

Table 6.0-8

Matrix Cell Summary

1 -208 +9	2 -41 +16	3 -20 +36
4 -31 +3	5 -51 +25	6 -13 +5
7 -58 +2	8 -14 +2	9 -21 +5

Table 6.0-9. Matrix Cell Causation and Relevancy Factors by Individual Case.

AA Case No	MATRIX CELLS 1	2	3	4	5	6	7	8	9
301	+ -		+	------ ++	- +	-	---	+	
302	------	-- +	-	+	--		--		
303	----	- +	++	-	---		---	-	+
304	-------- ---		--	-------	----		-----	-	----
305	----	-		- +		--- +	---------		
306	------	-	++	-	-	+	--		- +
307	-----	++	+		--	- ++			
308	----	-- ++	+	-	+				
312	------ +	---	-		--- ++	-	-		-
314	---- +	-	--						
315	--		+++		+		-		
316	-----		---- ++	-	-------	- +	-		+
318	-------	- +			-- +++			+	
319	--- +	-	+		++				
320	---- +	--		--	- +		--		
321	----	-- +	+	-	-				
322	---	-	+	-	--	-	--		

Table 6.0-9. contd.

AA Case No	MATRIX CELLS 1	2	3	4	5	6	7	8	9
323	-----	--	+		---	+	- +		-
324	-----						--		
325	-----		-	-	--- ++		--		
326	--	+	-	-	-	--	-	-	
327	----- +		-		++		+		
328	----	- +	-		- +			--	-
329	-------		+				--		
330	----- +	- +	+	--	- +		--		-
331	--	- +	+		-		-		
332	-----			-			--		
333	---	+			- +	-			-
334	--	-	+		+				
335	----	-	+		--				
336	----	-						-	
337	----	-	+	-			--		+
338	--		+	--	+		--		-
339	---		- +				-		

Table 6.0-9. contd.

AA Case No.	MATRIX CELLS 1	2	3	4	5	6	7	8	9
340	---		- +		+				
341	----		+		+		-		
342	-----	-					--		
343	---	-	- +		-	-	-		
344	----	- +					-		
345	--	-	+			-	--		
346	----	--			- +		-		----------
347	----		++		-	-			- +
348	-----	-	++	-					
349	----	--	+				--		
350	----	-			++		--		
351	--		+						
352	-----	- +	+		-	-	--		
353	------ +	- +	+				-		
354	--- +		--	--	---	-	-		
355	-----	--			-				

Table 6.0-10. MDAI Case Environmental Summary

[illegible]	Locality R = Rural U = Urban		No. of Lanes	Horizontal Configuration	Vertical Configuration	Significant Highway Data	Relevant Ambient Data
301	shopping or business	U	4/4	intersection	level 10/2	intersection	Overcast / dry
302	residential	U	2/2	intersection	many	intersection	Hot/intermittant showers
303	residential	R	4	straight	level	prior curve freeway	Overcast/humid
304	residential	U	2	multi-leg intersection	4.5^o	complicated intersection	Intermittant light rain
305	farm	R	2	straight	level	previous curve	Night/intermittant light showers
306	undeveloped	U	4	straight	$1\frac{1}{2}^o$	freeway	Clear/dry
307	farm	R	4	straight	level	freeway	Clear/dry
308	shopping or business	U	5/5	intersection	level	intersection	Clear/dry
312	undeveloped	R	4	straight	level	previous curve	Clear/dry
314	residential	U	3	curved	$1\frac{1}{2}^o$	slight curve	Clear/dry
315	shopping or business	U	4/2	intersection	$1\frac{1}{2}^o$	3-street intersection	Sunny/dry
316	farm	R	2/2	intersection	level	intersection	Sunny/dry
318	residential	U	2/2	intersection	level	intersection	Sunny/dry

Table 6.0-10. contd.

Case No.	Locality R = Rural U = Urban		No. of Lanes	Horizontal Configuration	Vertical Configuration	Significant Highway Data	Relevant Ambient Data
319	farm	R	2/2	intersection	loose	poorly maintained dirt roads	Clear/dry
320	undeveloped	R	4	straight	level	freeway	Sunny/dry
321	residential	U	4	straight	$2\frac{1}{2}^{o}$	luminaire pole	Light rain
322	residential	U	4	straight	$1\frac{1}{2}^{o}$	nearby intersection	Overcast
323	farm	R	2	straight	$\frac{1}{2}^{o}$	no lighting	Dark
324	residential	U	3	straight	$1\frac{1}{2}^{o}$	previous intersection	Overcast
325	residential	U	4	straight	level	previous intersection	Night/heavy rain
326	undeveloped	U	4	straight	level	freeway	clear/dry
327	shopping or business	U	4	slight curve	level	railroad crossing	Night/clear
328	shopping or business	R	4	curved	$\frac{1}{2}^{o}$	freeway snowy shoulder	Night/occasional snow
329	residential	U	4	straight	$1\frac{1}{2}^{o}$	nearby intersection	Day/misty/overcast
330	undeveloped	R	4	straight	level	freeway	Night/mist/occasional heavy rain
331	residential	R	2	straight	$\frac{1}{2}^{o}$	icy patches	Clear

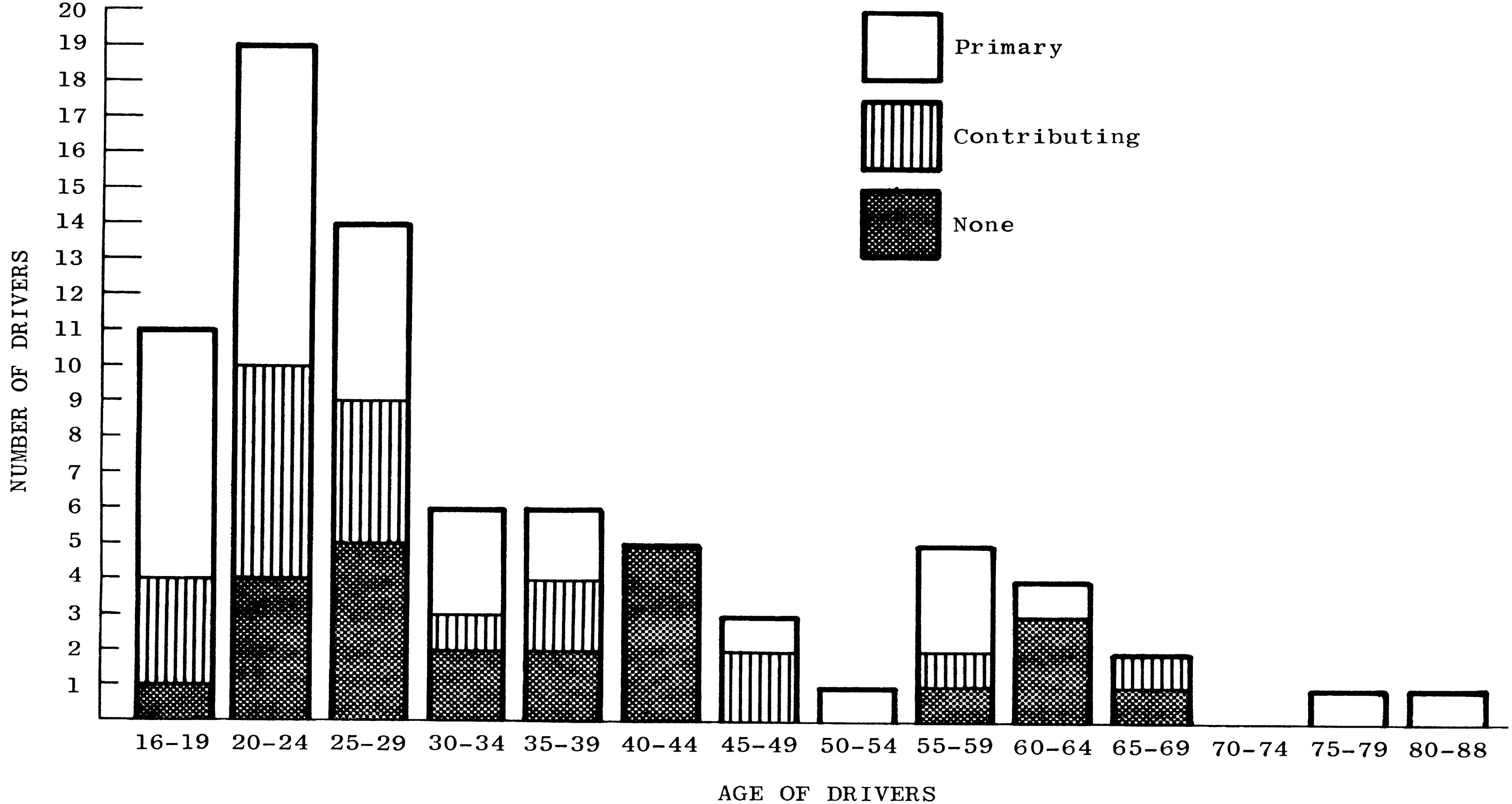
Table 6.0-10. contd.

Case No	Locality R = Rural U = Urban		No. of Lanes	Horizontal Configuration	Vertical Configuration	Significant Highway Data	Relevant Ambient Data
332	undeveloped	R	4	curved	$1\frac{1}{2}^{o}$	median guardrail	Cold/overcast
333	manufacturing or industrial	R	4	curved	$1\frac{1}{2}^{o}$	freeway	Sunny/dry
334	residential	R	2	straight	level	roadway icy	Sunny
335	shopping or business	R	4	straight	level	nearby intersection	Cloudy
336	undeveloped	R	2/2	curved	1^{o}	merging fork	Clear/dry
337	residential	U	2	curved	level	roadway icy	Sunny
338	farm	R	4	straight	level	ice patch	Sunny/windy
339	residential	U	4	straight	level		Sunny/dry
340	undeveloped/ golf course	U	5	curve	$2\frac{1}{2}^{1}$	intersection	Sunny/dry
341	school or playground	U	2	straight	1^{o}	intersection	Clear/sunny
342	farm	U	5	intersection	level	snowy lanes	Clear
343	shopping or business	U	2	straight	2^{o}	railroad crossing	Overcast
344	undeveloped	U	4	straight	$\frac{1}{2}^{o}$	previous curve	Overcast

Table 6.0-10. contd.

Case No.	Locality R = Rural U = Urban		No. of Lanes	Horizontal Configuration	Vertical Configuration	Significant Highway Data	Relevant Ambient Fact[ors]
345	residential	R	2	straight	level	chuckhole	Dark
346	farm	R	5	intersection	level	high volume	Overcast/rainy day
347	residential	U	4	straight	$1\frac{1}{2}^{o}$	approaching intersection	Partly cloudy
348	residential	R	2	straight	level		Sunny/dry
349	apartments	U	5	curve	level		Dark
350	residential	U	4	straight	2^{o}	narrowing roadway	Dark/street lights
351	residential	U	4	straight	$1\frac{1}{2}^{o}$		Overcast
352	farm	R	3	straight	2^{o}	service station exit	Sunny/dry
353	shopping or business	U	5	straight	level	previous intersection	Sunny/dry
354	residential	U	2	straight	2^{o}		Overcast/clearing
355	farm	R	2	straight	level	tree	Clear night

Table 6.0-11. Distribution of Drivers by Age, and Responsibility.



accidents. Approximately 50% of the 16 - 29 year old drivers were primarily responsible. None of the five drivers aged 40 to 44 initiated the accident. Two drivers over age 75 were primarily responsible for the accidents in which they were involved.

7.0 Human Factors

Those driver actions inappropriate to the human, vehicle, and roadway traffic environment (e.g. speeding, reckless driving, decision errors, and inattention) were observed in all of the in-depth case studies completed this past year. Driver behaviorism, directly or indirectly, was associated with life stresses. The more gross and obvious life stresses showed up during driver interviews, or were reflected in driving records. Presumably more subtle, hard to identify, but debilitating stresses also were present in many instances.

Driver behavior in the sample of all multidisciplinary case studies varied according to the life style, individuality, age, sex, and situation. Individuals under great stress were more frequently involved in accidents and had accumulated more moving violations. In this group of accident studies, drivers under stress were involved in more severe accidents associated with high speed, reckless driving, and alcohol. Of the twelve examples of such severe accident cases, eight included fourteen of the seventeen resulting fatalities. All drivers in these accidents were young to middle aged males, and all but one alcohol imparied driver lived under stress, as described herein.

The at-fault driver in AA306, a 30 year old black male, evidenced stress release in driving errors, speeding, and reckless driving. His past history indicated a pattern of impulsive, inconsiderate actions and overt hostility. Before the case high speed fatal accident, he had been in a severe fatal accident while drag racing, which resulted in the death of his brother. Although described by family and friends as a good natured, generous man, he was, in other environments, hostile and disruptive. At work he was unreliable. He frequently took time off with compensation for a minor physical disability, or went partying and drinking on a work day. Toward his co-workers and supervisors he was often hostile and threatening. He had been involved in such criminal activities as theft and drug dealing.

Usually a normal driver, he sometimes made "sloppy" driving errors and he liked to speed. A driver's license in his own name had expired and a license under an alias was suspended. In a four year period he had violations for speeding twice, an improper turn, and failure to signal. In four recorded accidents he was cited once for improper overtaking and twice for speeding. He was reexamined twice and three times failed to appear for reexamination. His license had been suspended for eight months prior to the accident in which he met his death, and he had one citation for driving while suspended.

Living under stress was illustrated in AA328 when the 28 year old male driver, an intelligent, innovative engineer and parttime student, who reportedly had worked 15 to 20 hours overtime weekly for six months, was described as a nervous, striving overachiever. After a weekend of work, alcohol impaired, he started out at midnight for his girlfriend's house which was an hour's drive away. Presumably alerted that he had drifted off the roadway by the sound of crunching snow, he evidently tried to recover and get back to the roadway but instead went into a fatal rollover. His driving record indicated violations that would result from stress or preoccupation -- e.g. disobeying a red traffic signal, running a red light, making prohibited turns, driving the wrong way, numerous notations for speeding, and two accidents in which he drove left of center, and one resulting from disregarding a traffic signal.

In several cases hazardous driving was directly associated with a specific stress situation. In AA303, for example, a driver with a near normal driving history, angered at being delayed by traffic congestion in a construction zone, slipped off the road edge while hurriedly passing a vehicle beyond the construction site. Again in Case AA335 an angry, intoxicated, male driver drove into the rear of another vehicle at high speed, following a family argument. He evidenced antisocial, hostile reactions and had had numerous speeding and reckless driving convictions and several prior accidents.

Degree and type of stress appear to determine the type and magnitude of driving error. A male driver who was in an accident following a family argument (AA335), was under stress to the point of emotional instability. He had had previous accidents, speeding and careless driving violations, as well as DUIL convictions. Another 28 year old driver (AA347) under moderate life stress had a history of speeding violations and accidents. A 21 year old male driver (AA355) who evidenced slight stress had previous speeding violations, but no previous accidents.

Stress was a factor in five of seven alcohol related accidents which were studied in depth. Overall life stress was present in four of these alcohol imparied drivers. For example, alcoholism and a period of depression characterized a 49 year old driver described as unfulfilled in work, marital, and social relations (AA305). He was fatally injured when,driving alone too fast for conditions, he overcorrected and left the roadway. In Case AA355, stress was indicated in a driver with a normal life history. A 21 year old, driving a high-powered "muscle" car for the first time, he lost control while speeding down a country road. In each of two other cases of alcohol related accidents the driver was distracted while conversing with passengers and left the roadway.

Male drivers under stress frequently are involved in severe collisions; female drivers under stress are overinvolved in accidents but not too severe collisions. Perhaps this difference is due to the male tendency to react to stress by high speeding and drinking,whereas the female tendency is to react to stress through various forms of preoccupation. All but one of nine collisions involving females under stress were attributed primarily to inattention alone*.

* A sole factor. Not "inattention and speeding", or "inattention and deliberate error".

A 24 year old woman (AA322), when travelling 10 mph over the speed limit, was unable to stop in time to avoid crashing into the rear of a stopped vehicle. Compounded by speeding, her perception and reaction time were delayed. The driver felt that, had she not been worried and preoccupied at the time, she would have perceived the situation more quickly and reacted faster to avoid the collision. Two weeks later she had a second accident resulting from a failure to observe an oncoming vehicle, and she felt that preoccupation again caused the accident. She had had two moving violations in the past year but none in the previous four years.

AA353 illustrated clearly lack of perception of an oncoming vehicle. A 22 year old woman driver was stopped in the turning lane of a busy thoroughfare, intending to turn left into a gas station driveway 40 feet from an intersection. She observed a cyclist approaching in the distance. Traffic was moderately heavy and she waited for a stream of cars to pass through the intersection past her. Then, focusing on a vehicle apparently stopping at the curb lane at the intersection, she decided the light was red to oncoming traffic and began to turn. At this moment the cyclist was 40 feet from her approaching at 35 mph, and a collision was unavoidable. A combination of information overload at a busy intersection and an incorrect assumption about the light being red contributed to the accident, although the cyclist was readily visible. Had the driver not made an impulsive and incorrect decision about the light, but instead surveyed the intersection as would a relaxed, alert driver, the accident would have been avoided. Stress was evident in the driver. The day of the accident she was fatigued from work. She was recently divorced, and bore the responsibilities for a job and rearing a young child. She appeared slightly nervous and flightly. In three years of driving she had received six moving violations (four for disobeying stop signs and two for speeding) and had been in two accidents. One accident occurred when she ran into the rear of a vehicle while lighting a cigarette. She was a heavy smoker. She stated, "I think I'm a good driver, attentive and careful". Understandably, she felt a little befuddled about this accident because she believed she had been cautious and was concentrating on her driving. However, she wasn't attentive to the whole environment.

A 20 year old woman driver was involved in a rear-end accident shortly after she had been released from a psychiatric hospital for treatment of a mental disorder and drug addiction (AA352). Although the driver appeared to be a quick, alert young woman, delayed perception was also a factor in this accident. She had similar rear-end accidents twice before.

Drivers having relatively balanced, unstressed life styles and average, or near average, driver records, also evidenced some of the same behaviorisms as drivers under stress (inattention, incorrect decision making, etc.) with the marked exception that they appeared not to take the risks (speeding, reckless driving, and driving while alcohol impaired) indulged in by male drivers under extreme stress. Subtle, unobserved stresses may have been present in all the other accident cases with some limiting effect on driver performance.

The most frequent accident driving characteristic found among the drivers in these case studies was inattention. There were two instances where drivers failed to heed railroad warning bells and lights; one a middle-aged woman out for a drive at night on her way home from work (AA327); another a young girl whose attention was fixed on a moving vehicle and green traffic signal at the intersection ahead (AA343). Driver inattention frequently results in accidents at intersections. For example, one distracted driver drove through a red traffic signal (AA301), and another driver absentmindedly followed the vehicle ahead of her into the intersection (AA318). In most instances, however, the at-fault driver stopped briefly, or not completely, at the intersection and then drove into the path of an oncoming vehicle. Often the other driver in the crash was unprepared for crossing vehicles, or was speeding.

Sight distance and confusing roadway design contributed to numerous intersection accidents. However, given such environmental conditions, one or the other driver could have averted the accident. Preoccupation due to stress appears to be the cause of driver inattention in such instances.

In two cases the driver made a deliberate decision to follow a dangerous course of action. In each instance the driver was preoccupied with an additional demand on his attention. One driver attempted to make an illegal U turn over an expressway crossover road in order to retrieve a jacket containing personally valuable items after it had blown out the window (AA307). On a dark, snowy night a truck driver also attempted an illegal U turn on an expressway median in order to get to tow a disabled vehicle (AA330). In each instance concentration on making the U turn took priority over other driving tasks. Each driver displayed mental impairment while acting on his decision. The first driver grossly misjudged the arrival time of an approaching cyclist. The second driver failed to note an overtaking vehicle in the passing lane.

Two accidents resulted from excessive speeding. A young male driver (AA337), speeding because he was late for work, crossed to the opposing lane while rounding a curve on a narrow street and crashed head-on into an oncoming vehicle. Another young male driver, "elated" from success at work, while speeding and inattentive, drove into a complex intersection and was struck in the side by a turning vehicle (AA307). His record showed speeding and "blocking" type moving violations and two previous accidents. In only two of the fifty in-depth case studies was the driver speeding in order to get to a specific place. In all other instances speeding seemed to be due to behavior under stress.

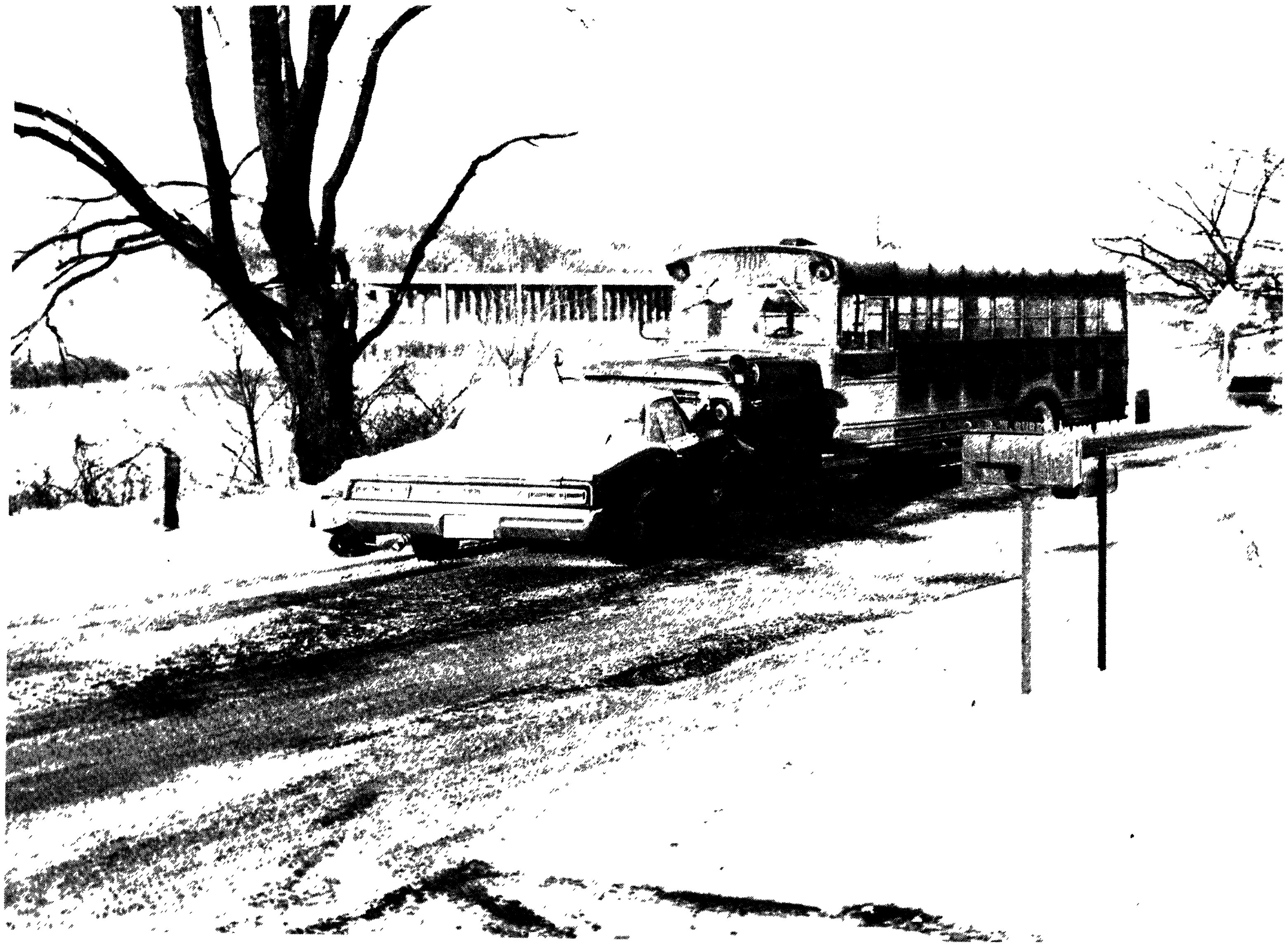


Figure 7.0-1. Speeding driver, late for work, risked crossing into opposing traffic lane on a curve.

Physical disabilities were relevant causal factors in some accidents. An undiagnosed prediabetic condition is believed to have contributed to driver failure to check for clearance at a yield sign on a country road, resulting in an accident (AA319). The driver had displayed symptoms of the disorder intermittently for several months prior to the accident. On the morning of the accident she had a headache, felt faint, and suffered from an upset stomach. The condition was diagnosed at the hospital after the accident. A young black female driver (AA314) passed out momentarily, crossed to the opposing lane, and collided with an oncoming vehicle. Recently married, burdened with the responsibilities for a young baby and a job, she was fatigued from lack of sleep and her work. She also was an inexperienced and fearful driver. A four foot-eleven inch woman afflicted with severe scoliosis (curvature of the spine) had difficulty adjusting to floor pedals, which resulted in a collision when she accidently depressed the accelerator pedal instead of the brake.

None of the accidents could be attributed to direct drug involvement. However drug usage by one female driver under stress both stemmed from and compounded her difficult life circumstances. Dietary habits appeared to be irregular among some of the case drivers, particularly drivers under stress. Several young drivers exhibiting stress symptoms suffered from ulcers and hyperventilation.

Two accidents involved elderly drivers. An 89 year old female driver decided to back up to an expressway exit and was struck from the rear (AA312). A second elderly driver either rolled through a stop sign (according to the other vehicle driver) or became so preoccupied with checking for traffic in one direction she neglected to check in the direction of oncoming traffic. Both drivers expressed unwarranted confidence in their driving abilities. Interviews with elderly drivers indicate a tendency for them to overestimate their driving competence. Driver licensing agencies, insurance representatives, and physicians could assist them in evaluating and improving their competency to drive. These two elderly drivers held outmoded concepts of roadways. Elderly drivers would benefit from information about roadway and traffic system changes.

There were seven case accidents in which the driver, trying to regain control, overcorrected. Two drivers were alcohol impaired, one driver was inexperienced, and one was an experienced driver of a motor home. In five accidents overcorrection contributed significantly to the cause of the accident. Also, in five cases the driver steered into the path of a vehicle crossing in front of him, or directly into the path of the opposing vehicle. In at least two instances the accident might have been averted had the at-fault driver steered in the opposite direction.

It is clear from considering these examples of driver behavior that impairments in driver functioning due to accumulated and immediate mental stresses do inhibit the driver's ability to be aware of and fully responsible to his environment. With the exception of the few instances of physical impairment, no inherent dysfunctions were observed in the drivers studied. Driver education and driver experience in terms of knowledge of the rules of the road and training in driving skills were, with several exceptions, found to be adequate. Conventional driver education does not appear to have a significant impact on accident incidence. Remedial driver training courses, suspensions, and revocations do not impress drivers who are under stress or accident prone. Considering the significance of stress in driver behavior as observed in these cases, it is evident that this factor should receive considerably more attention. Somehow experienced but non-performing drivers must be convinced that driving is a full time task not to be undertaken when impaired by alcohol, sickness, emotional stress or distractions in any form.

8.0 Vehicle Factors

Vehicle data required for in-depth case studies of selected accidents was gathered in two phases: (1) examination of all involved vehicles at the accident site; (2) detailed vehicle examination after post-crash disposition. Items checked at the accident site include vehicle year, make, model, body style, license number and color, possible vehicle defects, fuel leakage, tire condition, etc. Positions of controls for the wipers, lights, radio, heater, air conditioner, and windows and also vehicle final resting position are recorded. Vehicle skid marks are identified and the scene is photographed. Occupant seating location is noted along with restraint system availability and indication of use. The towing service that removed damaged vehicles, its operation, and its disposition of vehicles also are noted. After vehicle removal, debris and clean-up time are observed, and the overall post-crash scene is assessed. In the second phase each involved vehicle is thoroughly examined, usually at the towing yard. Both the standard CPIR Long Form and a vehicle maintenance report are completed. This maintenance report includes tire tread depth, brake fluid level, leakage, and pedal adjustment. The wheels of the accident damaged vehicles are removed and the brakes are examined. Drum style brakes are inspected for scaring and wheel cylinder leakage. The brake shoe lining is measured with calipers. Disc style brakes are inspected for scaring of the disc. The examination also includes assessing vehicle crashworthiness and noting component failure and crash performance. All damage is noted. Occupant injuries are obtained, either from hospital records or through occupant interviews prior to visiting the towing yard. This facilitates close examination of the occupant contact points and their correlation with occupant injuries. Equipment used in vehicle examination and evaluation include:

inclinometer

tape measure

small mirror

tire air pressure gauge

tread depth gauge

tool box

calipers

floor jack

jack stands

camera

strope

close-up lens

yellow contact tape (to indicate occupant contact)

Of the 50 case accidents completed during the past year, none were due directly to vehicle defects. In two cases stalled engines contributed to accident causation. Many vehicles showed lack of maintenance. Maintenance reports and observations of each vehicle indicated that of the 50 cases studied during the contract year, 13 involved vehicles that had one or more tires with 2/32 inches tread or less, which is considered to be unsafe. Of the 263 tires checked the average tread depth was 7.5/32 inch. In 15 accidents, 17 of the involved vehicles had more than 2 psi difference in the opposite left and right tires. Irregular tire wear was noted in 3 cases, and leaking or worn shock absorbers were found in 10% of the accident case studies. Three vehicles had damp, and possibly minor leaks in the master cylinder. Badly scored brakes were found on two vehicles, but were not considered a primary causal factor in the accident.

Ten vehicles had slightly degraded windshield wipers, and three had wipers that were broken or in poor condition.

Average odometer reading for all accident involved vehicles, excluding large trucks, was 34,000 miles.

TABLE 8.0-1

ACCIDENT VEHICLES BY MAKE AND MODEL

General Motors

Buick	1
Cadillac	2
Camaro	1
Chevelle	3
Chevrolet	2
Firebird	1
Grand Am	1
Grand Prix	1
Nova	2
Omega	1
Pontiac	2
Skylark	1
Tempest	2
Vega	2
	22

Ford

Capri	1
Comet	1
Cougar	1
Falcon	1
Ford	4
Maverick	5
Mercury	2
Mustang	3
Pinto	1
	19

American Motors

Gremlin	1
Hornet	1
	2

Chrysler

Chrysler	1
Dart	1
Duster	2
Plymouth	2
Valiant	2
	8

Foreign

Fiat	1
Volvo	1
	2

(Total Cars 53)

Buses, Trucks, Recreation Vehicles

6 x 6 Army Truck	1
GMC Tractor-Trailer	1
Ford F700 Swinger Motor Home	1
Diamond Reo	1
Ford School Bus	1
IH Loadstar School Bus	1
	7

Motorcycles

Harley Davidson Sportster	1
Suzuki 750	1
Kawasaki 500	1
Suzuki 350	1
Honda 175	1
	5

Pickups, Vans MPV

Jeep Mail Truck	1
Ford Bronco	1
	2

TABLE 8.0-2

ACCIDENT VEHICLES BY MODEL YEAR

Vehicle Model Year	Cars	Pickups, Vans, MPV	Buses, Trucks Rec. Veh.	MRTCY	Total
'52	0	0	1	0	1
63	3	0	0	0	3
64	1	0	0	0	1
65	0	0	.	0	1
66	6	0	0	0	6
67	1	0	0	0	1
68	5	0	1	0	6
69	1	0	0	0	1
70	9	1	1	0	11
71	14	0	1	1	16
72	9	1	1	3	14
73	4	0	1	1	6
	53	2	7	5	67

(Does not include vehicles that struck pedestrians or motorcycles.)

TABLE 8.0-3

PRINCIPLE DIRECTIONS OF FORCE TO VEHICLES IN MULTIDISCIPLINARY ACCIDENT INVESTIGATIONS

Direction or Type (O'clock)	No. of Impacts Contract Year	No. of Impacts CPIR File	Percent Contract Year	Percent CPIR File
Frontal (11, 12, & 13)	30	2042	50.8	62.7
Rear (5,6, & 7)	9	264	15.2	8.1
Left Side (8, 9, & 10)	10	461	17.0	14.1
Right Side (2, 3, & 4)	10	489	17.0	15.1
	59*	3256	100	100

* Does not equal number of vehicles involved (63) since four were rollovers and therefore not classified by these categories.

TABLE 8.0-4

General Area of Damage	Number Contract Year	Number CPIR	Mean Extent of Damage* CPIR	Mean Extent of Damage* Contract Year
Frontal	30	1946	2.60	2.53
Back	9	227	2.70	3.66
Right Side	10	506	2.89	3.20
Left Side	10	520	2.8	2.20
Top	1	136	3.76	3.00
Undercarriage	1	39	2.43	1.00
Unclassifiable	2	124	3.03	3.50
Total	63	3498	2.74	2.75

* The CDC (Collision Deformation Classification) describes the contact deformation of a vehicle. This was used to compare the cases of this contract year with those in the CPIR file.

Some general characteristics descriptive of all the accident vehicles examined are presented in the following tables; Vehicles by Make and Model (Table 8.0-1), Model Year (Table 8.0-2), Principle Directions of Force (Table 8.0-3), and General Area of Damage (Table 8.0-4).

For each case accident the motor vehicle safety standards were assessed relevant to causation or production (or lessening) of injury. Table 8.0-5 presents this information in summary form; the details are in each case report.

In addition to the CPIR "Long Form" and Maintenance Report Form described earlier, a separate form included as Figure 8.0-1 was used to collect data regarding seat belt type and utilization, by-passing techniques or buzzer alterations. Since September 1972 accident investigators in Oakland and Washtenaw Counties have used these forms. However, because such data is sparse* it has not yet been incorporated into data files.

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* Buzzer systems have only been mandatory in 1973 model year vehicles.

TABLE 8.0-5

RELEVANCE OF
MOTOR VEHICLE SAFETY STANDARDS;
A MULTIDISCIPLINARY ACCIDENT INVESTIGATION

MVPS Number	Title, Relevance, AA Case Number	
101	Control Location, Identification and Illumination	
	(333)	driver unfamiliar with location of vent control knob
103	Windshield Defrosting and Defogging Systems	
	(325)	window fogged in crowded vehicle on rainy night
105	Hydraulic Brake Systems	
	(352)	brake pedal almost to floor, low brake fluid
108	Lamps, Reflective Devices, and Associated Equipment	
	(348)	poor location of vehicle turn signal lights
111	Rear View Mirrors	
	(323)	Multiview rear view mirror, injury producing
122	Motorcycle Brake Systems	
	(347)	driver failed to employ independently activated front brake
201	Occupant Protection in Interior Impact (PC1-1-68)	
	(301)	postal "jeep" type vehicle with unpadded instrument panel
	(302)	injury from striking unpadded door
	(302)	plastic convenience tray caused injury
	(305)	injured from shattered plastic under instrument panel
	(312)	breakaway mirror did not break away
	(312)	ashtray flew out, not injury producing
	(316)	severe crash caused many injury producing agents
	(319)	injury from plastic covering on "A" Pillar
	(331)	driver injured from broken heater ducts
	(321) (342)	injury received from striking unpadded surfaces
	(322) (345) (346)	injury producing control knobs
	(304) (308) (318) (319) (320) (325) (327) (332) (334) (337) (340) (344) (346) (350) (355)	Padding present may have reduced injuries

202 Head Restraints

(301) vehicle exempt, MPV
(312)
(352) pre-standard vehicle, no head restraints, rear-ended, no injury

(322) (333)
(334) (335) head restraints equipped, minimized injury in rear-end accident

(352) vehicles with head restraints had drivers who received whiplash injuries

203 Impact Protection for the Driver from the Steering Column System - PC(1-1-68)

(301) MPV exempt
(312) driver contacted steering wheel with no EA device compression, uninjured
(335) pre-standard vehicle, no EA device, injury producing

(330) (345)
(346) performance of EA device adequate

(305) (306) (323)
(325) (355) EA device performance questionable

204 Steering Control Rearward Displacement

(304) foreign car had double U joint design
(305) rearward displacement one inch
(350) engine compartment unit compressed 2.5 inches

205 Glazing Materials (1-1-68)

(320) did not have jagged pieces, 15 inch rip
(355) drivers head ejected outside glass

(308) (319) (325) (328)
(342) (345) (346) (350)

struck w/s cracked, no jagged pieces

206 Door Locks and Door Retention Components PC 1-1-68
MPV 1-1-70
Trucks 1-1-72

(304) hinges and latch separated
(306)
(328) severe door damage, remained latched
(308)
(316) pre-standard vehicle door opened, driver ejection

Table 8.0-5 (cont.)

206 (cont.)

	(318) (355)	driver door opened, driver ejected
	(319)	latch released, door remained closed because of sheet metal damage
	(343)	severe crash door opened, no ejection
207	Anchorage of Seats PC 1-1-68 (1-1-72 MPV)	
	(305)	seat anchorage failed
	(325)	seat back locks held prevented injury
	(304) (306) (312) (322) (333)	seat remained anchored despite severe seat back defamation
208	Occupant Crash Protection	
	(330)	occupants using lap belts, pass needed S/H to prevent fatal injuries
	(308) (319)	Occupants being belted would have reduced injuries
	(326) (331) (344)	occupants using lap belt(s)
209	Seat Belt Assemblies	
	(302)	driver assumed buckle had locked, released on impact
	(328)	locking retractor may have slipped
212	Windshield Mounting (1-1-70) Pass Car	
	(355)	severe crash more than 50% bond separation
	(337)	pre-standard vehicle more than 50% bond separation
	(308) (332)	MPV exempt 100% bond separation
	(325)	tree impact 100% bond separation
	(316) (323)	pre-standard vehicle severe crash 100% bond separation
213	Child Seating Systems	
	(318)	child in safety seat (uninjured)
214	Side Door Strength	
	(304) (308) (316) (343)	pre-standard vehicle may have benefited had it been equipped with side beam
	(318) (319) (327)	pre-standard vehicle benefited from side beam
	(306)	pre-standard vehicle equipped with side beam had little effect because of severity

Table 8.0-5 (cont.)

216	Roof Crush Resistance		
		(328)	vehicle pre-standard but little inward crush
		(320)	pre-standard vehicle significant crush
		(332)	MPV exempt from standard (inward crush at header)
		(316)	pre-standard vehicle roof into pole significant roof crush
301	Fueltanks, Fuelfiller Pipes, and Fuel Tank Connections		
		(301)	damaged tank of MPV fuel leakage
		(306)	damaged tank no fuel leakage
		(316)	fuel leakage in pre-standard vehicle, shock absorber contact
		(322)	fuel tank punctured, leaking fuel
		(333)	severe tank deformation, leaking from float assembly for full gauge
		(335)	ruptured fuel tank in rear-ended vehicle
		(338)	filler pipe pulled from tank (MPV exempt)
		(345)	no leakage from scuffed tank, leakage from filler pipe
		(352)	pre-standard vehicle rear-ended, fuel leakage
		(312) (343)	filler pipe pulled from tank
		(355)	scuffed tank, no leakage
302	Flammability of Interior Materials		
		(335)	pre-standard vehicle - destroyed quickly by fire
		(338)	motor home vehicle destroyed quickly by fire

1972 SEAT BELT DATA

AA	WC	OK	UM	NO

make	model	vin

BELTS: 3-point ☐ 4-point ☐ other:

Buzzer Equipped: YES ☐ NO ☐ UNK'N ☐

System Inhibited: Belts fastened together ☐ Buzzer wire cut ☐ Unit removed ☐ Belt knotted above sensor ☐

OTHER:

CIRCLE

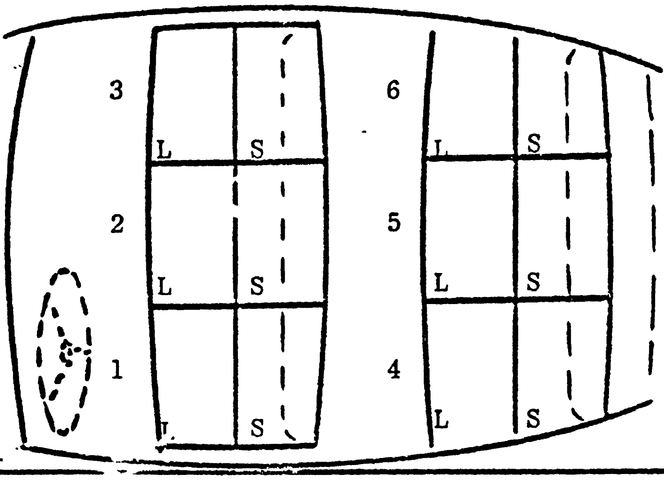
Number for occupant position

CHECK

L for lap restraint use

S for shoulder restraint use

NOTE IF UNKNOWN



Investigator______________

Notes:

Figure 8.0-1

Restraint System Assessment

9.0 Environmental Factors

The 50 multidisciplinary accident investigation case studies completed this past year were reviewed to determine how the environment (the roadway, traffic information and control systems and adjacent development) contributed to the occurrence or amelioration of these accidents.

Because the 50 case accidents are not a random sample of the Washtenaw County accident experience for the year, the frequency of certain environmental elements appearing in the study will be a biased reflection of the role of the environment in accident causation. On the other hand, they do offer some insight as to the causal contribution of these elements that should benefit highway designers, builders, maintainers, and operators.

9.1 Environmental Contribution

In this set of 50 case accidents, there were only eight in which it appeared the environment did not play a part*. This does not imply that there were no environmental deficiencies at these sites, merely that they did not appear to be in any way relevant to the chain of events occurring prior to, during, or immediately following the accident.

9.2 Roadside Obstacles and Guardrails

Throughout Washtenaw County various roadside improvement programs have been in effect for a number of years, but because of size of the highway "plant" and the limited resources,

* The eight cases are: AA314; AA321; AA323 (a homicide-suicide); AA327; AA334; AA347; AA348; AA354.

both in men and money, allocated to these improvements they have not had a large impact on the traffic accident situation. These improvements are designed to prevent accidents, or to ameliorate their effects when vehicles leave the roadway, by removal of nearby obstacles such as trees and boulders, reshaping ditches and slopes, making necessary signs easy to break without causing undue damage to the vehicle or its occupants, and most importantly, improvement of guardrail design and application so that a deviant vehicle will not cross into opposing traffic streams or crash into obstacles some distance from the roadway.

Of course, the major problem in assessing the value of environmental inprovements is the inability to detect the accidents that did not happen because of obstacle removal or other changes.

Some obvious successes of roadside improvement programs noted in this study are the following:

1. A breakaway luminaire pole close to the curb in an urban environment was struck and broke away as expected (Case AA301). In older commercial areas the lack of opportunity to place utility poles, luminaire standards, fire hydrants, etc. a satisfactory distance from the travelled way necessitated this type of approach.

2. The existence of a clear 80 foot area to the right of a multi-lane merging area ameliorated the severity of an accident involving an out-of-control vehicle which had collided with another vehicle in the merging area (Case AA336).

3. A recently constructed urban parkway was built to modern standards. In Case AA344, an out-of-control vehicle left the roadway and decelerated on an appropriately designed upslope that had been cleared of trees to the desirable distance of 30 feet from the roadway. The decelerations experienced were low and the severity was low. Interestingly, an element contributing to the loss of control was the presence of a fire hydrant in the median close to the end of the pavement which the driver was trying to avoid. However, this fire hydrant, unknown to the driver, was of the break-away design.

Figure 9.2-1. Absence of median barrier permitted vehicle to cross into on-coming traffic.

Figure 9.2-2. Path of Pinto that left roadway of urban parkway. Vehicle is in final resting position on right upslope of bank. (AA 344).

There were several examples of obstacles contributing to increased accident severity. A tree in the direct line of travel of a vehicle which failed to negotiate a curve contributed to the severity of an urban major street accident (AA325). Utility poles and trees located very near the curb immediately beyond a roadway width reduction contributed to the severity of an accident (AA350). A roadside obstacle near a freeway played a role in one case accident when a vehicle left the roadway and struck a tree closer than 30 feet to the road as the driver attempted to avoid an upside down vehicle which had crossed the median (AA320).

The rural two-lane road (often a low volume and low standard country road) presents a large number of off-road obstacles that contribute to the severity of the many single vehicle accidents which occur after dark. In the cases observed, (AA305) a bridge rail was struck, and (AA355) a tree was struck.

The use of guardrail in freeway medians whose widths are inadequate requires special attention. Several of the accidents studied undoubtedly were more serious than they should have been because of the absence of a guardrail or median barrier dividing the two roadways.*

In four cases the guardrail geometry was inadequate. In Cases AA326 and AA328 the length of guardrail protecting out-of-control vehicles on an Interstate Highway was insufficient. Height of the median guardrail was not adequate in one accident (AA332) and the guardrail was substandard in another situation (AA333).

Guardrails are vital for the out-of-control accident on two lane roads. An example of the contribution to accident severity resulting from the absence of guardrail is case study AA305. Although not important in case study AA337, the accident site was a narrow urban two-lane bordered by a sharp drop to a river where there is no guardrail protection.

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* A partial list of cases with this characteristic include AA303; AA306; AA320; and AA330.

9.3 Roadway Design

Highway designers have had to change or upgrade design standards in response to motorist errors or inability to use highway facilities properly. This often happens when excessively high construction costs of original designs require cost cutting modifications. A good example is the decision to eliminate or reduce the width of shoulders on bridges. The problem created may be seen in accident case AA312 in which an elderly woman driver backed to a freeway exit ramp after having passed it. She used the right travel lane because there was inadequate shoulder width available due to structured design.

Often the present designs do not respond to the illegal actions of many motorists. In accident cases AA307 and AA330 illegal U turns were made on a freeway, one at a crossing made for police and emergency vehicles only and another on the flat median (the narrow median may have been so designed to minimize the effect of a deep "V" cut on an out-of-control vehicle).

Highway designers recognize that motorists must have adequate perception-reaction time to make their decisions. Large signs, often placed over the road on freeways, facilitate this process. However, in some situations not enough reaction time is provided (AA312). At complex intersections a large roadside sign placed on a major urban arterial to inform motorists of a nearby freeway interchange may restrict sight distance of motorists exiting from an adjacent heavily used private driveway (AA342).

Roadway illumination often is one of the most effective highway safety measures available to engineers. Poor illumination in an urban area contributed to the crash in accident case study AA325.

Certain design elements which contribute to accidents obviously are oversights. For example, in case study AA303, a curve to the right on an interstate highway was designed with a narrow left hand shoulder which could not be maintained at the same elevation as the edge of the roadway. A vehicle failing to negotiate the curve could go out of control when "falling" into the rut adjacent to the road surface.

In another example,the combination of guardrail height, median elevation,and curb design negated the effectiveness of the guardrail in preventing an out-of-control vehicle from vaulting the guardrail on a right curving freeway (case study AA332).

A recently improved two-lane urban collector street was designed without standard pavement widening on a small radius curve despite its use by vehicles as large as school buses (case study AA337).

Private driveways, serving a commercial "truck stop," were located too close to the ramps of an interchange between a freeway and a primary state route (case study AA352).

A dropped lane often is not apparent to the driver. In case study AA342 a special left-turn lane had ended,and the driver suddenly was forced to alter his direction. This diverted his attention from a vehicle exiting from a private drive and resulted in a collision. In case study AA350 the driver was unprepared for a substantial narrowing of the outer lane of a major four-lane arterial immediately over the crest of a hill.

9.4 Maintenance

Design failures (case study AA303) often must be counteracted by continuing and expensive maintenance. Failure to maintain shoulder grades is a constant source of trouble (case study AA320). Ice on an interstate highway, together with snow on the shoulders, a maintenance problem, contributed to a spectacular accident involving a motor home that caught on fire when the vehicle was travelling 65 miles per hour on pavement in unsafe condition for such speed (case study AA338).

Failure to routinely clean ditches on a two-lane rural road caused water to flow onto the road surface and freeze, creating an icy patch which initiated an accident (case study AA331). Trying to avoid a large pothole precipitated another accident (case study AA345).

Improper maintenance resulted in development of a ramp that nullified the effectiveness of a median guardrail (case study AA323).

The many motorcycles now travelling streets and highways require that maintenance crews remove the sand and gravel, originally placed to provide traction on snow and ice, once the roadway is clear and dry (case study AA349).

9.5 Traffic Operational Considerations

Allocating the right-of-way at intersections can create safety problems, particularly if the major traffic flow must yield to the minor flow, because motorists who cross the intersection frequently often do not appreciate the need and tend to disregard the control. In case study AA316 an accident occurred at a rural cross intersection where the minor road was assigned right-of-way by a yield sign on the major road. When traffic flows in all directions are extremely low these controls become very ineffective, especially when the roads are surfaced and the only control is a "yield" sign (case study AA 319).

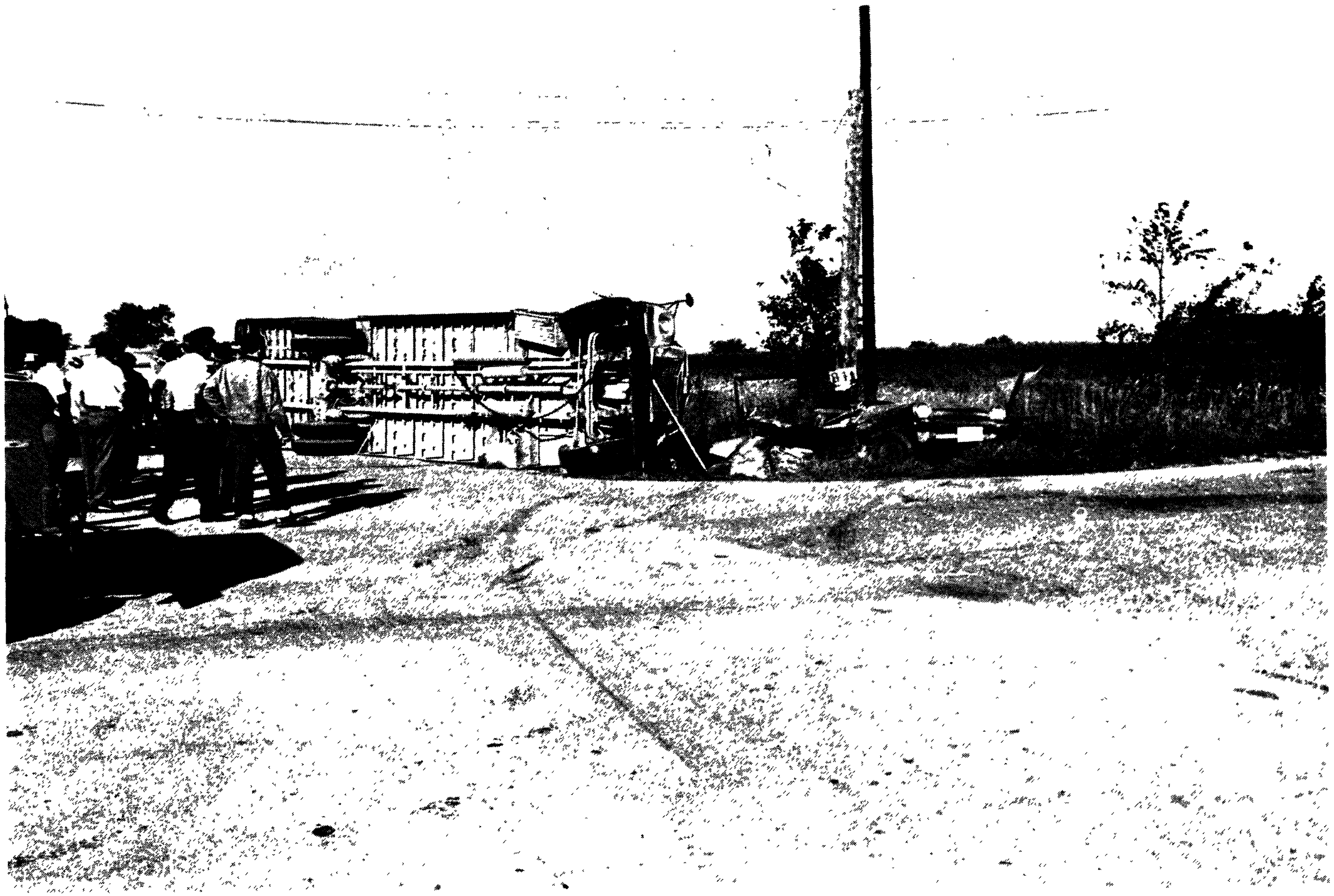

Figure 9.5-1. School bus accident scene at rural intersection, where major flow route must yield to minor flow route. (AA 316).

Traffic information and control devices must be placed where they can be easily and naturally seen. In case study AA343, the railroad grade crossing warning crossbuck was not located on the natural line of sight of approaching motorists.

When major arterials become lined with commercial developments that compete for visual attention, especially in heavy traffic, drivers frequently fail to see and heed traffic control devices. Such was the situation at one of the highest accident frequency intersections in the county (case study AA 346).

Traffic engineers have developed new techniques and devices with great possibilities for improving highway safety. However, local governments have difficulty financing the costs of these advanced techniques when it appears that benefits accrue to private individuals or when the magnitude of the traffic safety problem is not realized. In case study AA308 an ambulance on an emergency call violated a red traffic signal and collided with a passenger car. Radio actuated right-of-way override systems available for several years probably would have prevented this accident.

Traffic engineers should carefully monitor high-accident rate, signalized intersections in order to determine whether increased safety would result by periodically allocating the right-of-way to non-conflicting streams of traffic,even though it results in additional delay and reduced capacity.

An accident at one of the highest accident frequency locations in Washtenaw County involved a crash between a turning and a through vehicle, apparently because there was no separate left turning phase (AA 346).

New traffic information and control devices do not always work as intended. In some advanced flexible traffic signal control systems the driver knows only what is displayed visible to him. In simple systems he can infer the display visible to others. In case study AA 353 it appears that the at fault driver erroneously assumed that the opposing stream of traffic, like him, also faced

Figure 9.5-2. Van type ambulance after colliding with vehicle within a signalized intersection, when moving against a red traffic signal. (AA 308).

a red (or stop) signal and that he could make a quick left turn, when in reality the opposing stream had a green light, so a collision occurred.

9.6 Non-Motorized Road Users

Traffic engineers and planners have had difficulty trying to protect non-motorized highway users: pedestrians and bicyclists. Among the 50 multidisciplinary accident case studies this shortcoming appears in six cases.* The problem situations vary from local individual crosswalks to whole neighborhoods, school areas, and recreation centers, where children come in conflict with vehiclular traffic. As an example of poor coordination among traffic control agencies, the state highway department increased the speed limit on a major arterial in a residential area under its jurisdiction where two previous fatal accidents had occurred due to inadequate pedestrian crossing controls (AA 324 and AA 329).

9.7 Planning Considerations

It is a well established fact that good street system design can significantly reduce urban traffic accidents (recent British new towns have outstanding traffic safety records). Even in developed areas it is possible to change geometry and control so as to achieve a functional stratification of streets that provides for different levels of trade-off between land access and movement. Those routes dedicated to movement (freeways and expressways) have much safer records (on a rate or trip basis) than do local streets and collectors. In developed areas, minor physical improvements and traffic controls (such as one-way streets and four-way stops) help to reduce accidents. By geometric changes, the much safer T intersection can be adopted. The accident case studies undertaken in 1972-73 show how implementation of these practices could have made some accident avoidable.

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* AA 315, AA 324, AA 329, AA 339, AA 341, and AA 251.

For example:

1. A collision at the cross intersection of a local and collector street (Case study AA 302) involved a vehicle moving on a collector street at about 40 mph, a speed suitable only for a major arterial. The sight distance and traffic control were inadequate, a common shortcoming at this type of intersection.

2. An inattentive and upset motorist, while chasing another vehicle, collided with a car at a cross intersection in a residential area where a grid type street pattern is not justified (AA 318).

In some historic urban areas where the early settlers developed radial and natural routes leading from river ports, a regular grid or some other street pattern later was superimposed, resulting in complex intersections. Washtenaw County has such intersections, a result of the days when slow-moving horse-drawn wagons predominated. Such intersections are unsatisfactory today. Many of the approaches are still important, but intersection capacity is limited and traffic information and controls are complex or confusing for motorists, so numerous accidents occur. Several accident case studies bring this out, particularly (AA 304) wherein the accident site was a complex intersection on a hillside where six important routes merge. However some channelization improvements were made shortly after this accident.

In case study AA 340, a vehicle was involved in an accident while travelling on a recently completed urban parkway which requires relatively low driving attention, except for one complex intersection surrounded by distracting land uses and curved approaches. The accident in case study AA 325 occurred at a poorly designed Y intersection of major streets.

Left turning vehicles are a constant source of accidents. Four case studies reflect this problem (Cases AA 322, AA 335, AA 342, and AA 353), which could be saved by better traffic planning and routing.

A more complex problem is an urban railroad grade crossing, the location of several accidents this year (Case studies AA 327, and AA 343). Case study AA 352 demonstrates the effects of improper design on flow of trucks into and out of driveways and through private property service areas.

Although a review of the primary or principal causal factors in accidents indicates that driver error or poor judgement* far outnumbers other considerations, the environment most often stands out as an influencing or relevant factor. In 42 of the 50 in-depth case study accidents vehicle trajectories, crash severities, and resulting occupant injuries could be attributed to the roadway design or the dynamic environment. The observations and findings of these in-depth studies of selected accidents should assist highway planners, designers, and maintenance managers.

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* See Section 6.0 for tabulations of accident cell factors cited in the 50 MDAI case studies.

10.0 Special Studies

This section includes a variety of topical areas relating to highway safety which were considered throughout this program. The selection of these topics was prompted by inquiries resulting from some problem or accident phenomenon observed by field accident investigations. An attempt has been made to answer specific questions as they relate to these observations, using the accident data files described earlier where possible.

A total of seven subjects are included. These range from a statistical description of large and small car involvements in accidents to seat belt retractor performances and illustrate the versatility of the tri-level approach in examining various highway safety problems of interest.

10.1 Small Car-Large Car Study

Disparities in the masses and sizes of vehicles has long been a matter of concern to transportation specialists and safety researchers because of the relative damage and occupant injury which occurs. Many of the multidisciplinary accident case studies* show that crashes between large and small vehicles result in wide variations of damage and injury to the respective vehicles and occupants. The detailed causation factors and relevant findings in these case studies include discussion of the broader problem of size disparity between vehicles.

In accident case study AA 151, for example, a full size sedan crashed into a foreign sports car in an oblique, head-on, orientation. The sedan driver sustained injuries classed as AIS-2 (moderate) while the sports car driver injuries were classed as AIS-7 (fatal lesions of single region of body, plus injuries of other body regions, severe with survival uncertain). This study stressed the effects of vehicle size and structural differences. It was noted that "while no recommendation is offered here, perhaps the compromise in safety when driving a small foreign sports car in a vehicle population dominated by full size vehicles should be

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* The reader is referred to HSRI multidisciplinary accident case studies AA 140, AA 151, AA 145, AA 153, AA 200, AA 302, AA 304, AA 312, AA 318, and AA 319.

Figure 10.1-1: 1969 Fiat impacted in left side by 1971 Ford station wagon. AA 304.

Figure 10.1-2: Gremlin impacted by full-size pickup truck.

stressed more to the motoring public." Other illustrations of crashes between dissimilar size vehicles are shown in Figure 10.1-1 and 10.1-2.

To better understand these differences, a statistical study was made to assess the risk of injury in small and large cars in collisions. This effort resulted in the preparation of a technical report which was presented at the Automotive Safety Seminar*, hosted by the General Motors Corporation on June 20, 1973.

In this study various data sources were utilized to accurately classify vehicles according to weight, total vehicle population, vehicle use, characteristics of their drivers, use of installed restraint systems, and injury producing accidents involving these vehicles. In general, the study confirmed many conclusions regarding small cars drawn from other research, such as that the risk of injury to occupants in accidents is greater, that they are over-represented in one car accidents, that their drivers are younger, and that generally they contain fewer occupants.

Most significantly, the study quantitatively established the comparative risk of injury to occupants of vehicles in various accident configurations relative to the weight of the vehicles. From this data, injury rates were predicted as a function of the change of the vehicle size "mix" in the American overall vehicle population. See Appendix A for the complete technical report, "A Statistical Description of Large and Small Car Involvement in Accidents".

10.2 Parked Car Accidents

Investigation of accidents which involved parked cars was limited to the Level II or crash phase this past year. Such accidents were severe in terms of property damage and injury.

In one accident a tractor and semi-trailer combination struck the rear of a similar truck combination which was parked on the

* GM Training Center, Warren, Michigan.

shoulder of an interstate highway because of some minor mechanical malfunction. There was near complete overlap of front and rear between the striking and parked vehicles. Both driver and helper in the striking truck, which was an interstate moving van, sustained severe non-fatal injuries. This accident occurred at 7:30 a.m. on a bright, clear, summer day with unlimited visibility. The interstate highway section was level and straight and not near any interchange. Traffic was very light and free flowing. The striking vehicle, a moving van, had loaded up at a Canadian city 200 miles distant, about four hours earlier. Both the driver and his helper had exhausted themselves loading and had taken no intermediate rest stops. Therefore, the driver, drowsy and inattentive, and somewhat eurphoric, thought the parked truck ahead was moving in traffic and he struck it without any braking or taking evasive actions

In another interstate highway accident, a parked police patrol car was struck in the rear while the officer was investigating an earlier accident. The striking vehicle was on the climbing, left turn, upper most bypass of a 3-leg Y-type interchange. Apparently the driver lost his points of reference due to vehicle speed and highway elevation while turning, so he collided with the rear of the patrol car parked on the shoulder of the roadway in broad daylight with its red emergency lights flashing. The driver also appeared to be distracted by the flashing emergency lights while navigating a complex portion of the interchange at high speed. All factors combined to affect his performance. He attempted no pre-crash braking or avoidance maneuvers.

A more tragic accident of this type occurred one night in February 1972.* A father and daughter were standing between their respective vehicles which were parked with the lights on well off the roadway on the shoulder of a two-lane rural roadway, when one of the cars was struck in the rear. The collision impelled their cars together with great force. Both father and daughter (52 and

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* Accident case study AA 169.

21 years respectively) sustained serious injuries resulting in traumatic amputation of lower limbs. The driver of the striking vehicle was intoxicated.

These parked vehicle accidents led to an assessment of the scope, frequency and severity of such accidents. Questions like, "how many accidents involve parked vehicles?" "how many involve injuries?" "how do they occur?" "under what conditions do they most often occur?", were posed. As a first step, mass accident data (Level I Police Reports) were examined and it was found that the majority of such accidents occur at low velocity impact on urban residential streets, usually are less severe than other accidents, and generally are minor "fender bender" collisions, initiated by a driver backing into a car parked in the street.

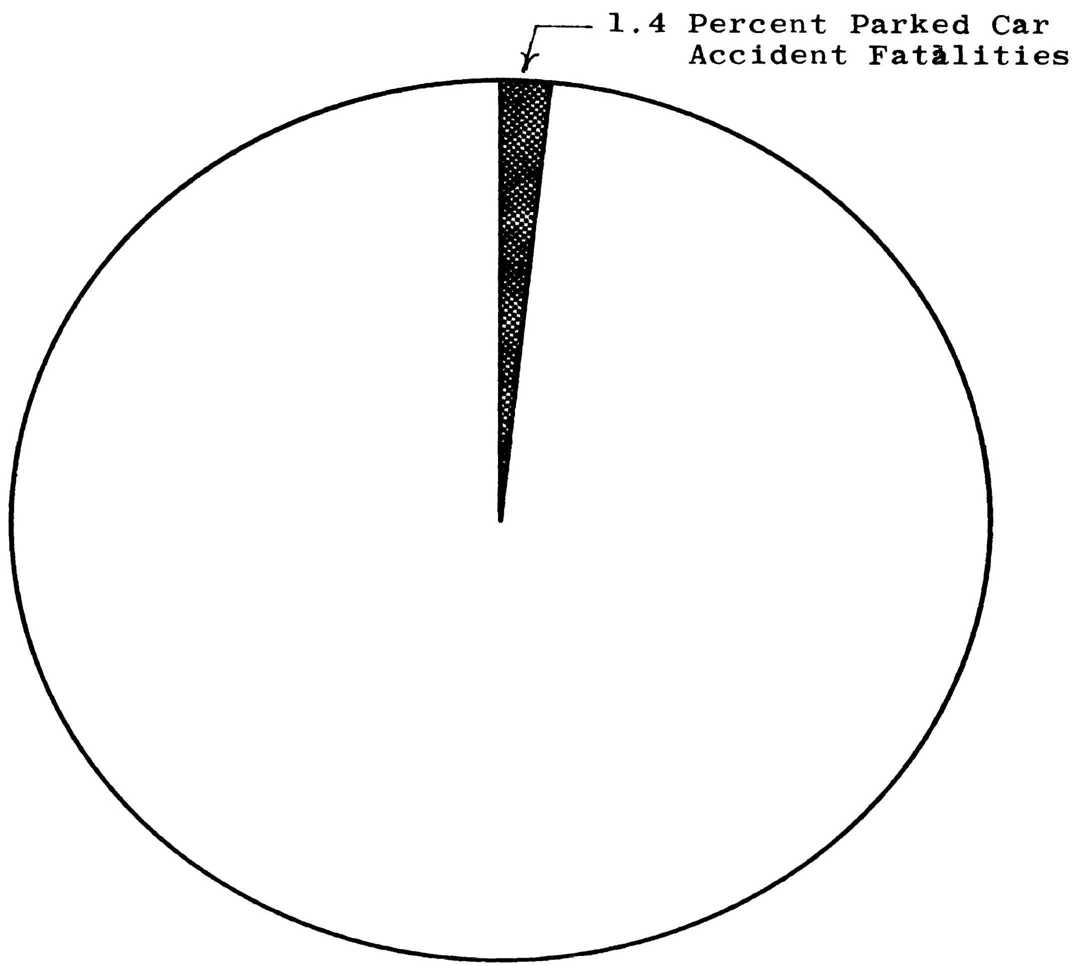
Examination of accident data nationwide indicates that coding of "parked car" accidents varies among the states. Even in those states which specifically identify this type of accident, the percentage of parked car collisions varies widely, indicating that the term "parked car" on the accident report is interpreted differently among jurisdictions. For example, in North Carolina parked car accidents in a recent year constituted 0.9% of all reported accidents, 3.6% of injury accidents and 1.3% of all fatal accidents. In Michigan, 1.8% of all fatal accidents involved parked cars.

To separate the more serious parked car accidents from those of the "fender benders" which occur mostly on residential streets, all Washtenaw County identifiable and reported parked car accidents were computer scanned. A listing was then reconstructed of parked car accidents which occurred outside of the two major cities, Ypsilanti and Ann Arbor, which totaled 850. From this list there were filtered a substantial number of accidents of the "fender bender", residential street variety, and a second list of 174 cases which included only injury (including fatal injury) accidents occurring outside city limits.

The "hard copy" police reports corresponding to these accidents were reviewed to obtain some understanding of the circumstances surrounding each accident. In 1971 there were 47 injury and fatal injury parked car accidents. Twenty-two occurred on limited access highways, of interstate or equivalent highway standards. Causation comments on the police reports for these accidents were:

Previous accident	7
Police vehicle (flashing light)	1
Other official highway vehicle (yellow flashing light)	1
Mechanical trouble	3
Driver sleeping	1
Construction trailer	1
Stopped in roadway (reason not stated)	2
Stopped on shoulder (reason not stated)	6

To determine the relative lethality of these accidents, both Michigan and Texas data files were examined. Parked car accidents, on an average, seem to be less severe than other accident categories in Texas accident data. However in Texas these accidents occur more frequently. The number of parked car fatal accidents reported in Texas over a three year period is 44 (1969), 37 (1970), and 52 (1971). In Michigan there were 35 fatal parked car accidents in 1971. Using these figures, a gross projection can be made nationwide by comparing the total U.S. population with that of the two observed states. The Texas and Michigan populations total about 20,000,000. The total number of Michigan and Texas parked car fatal accidents in one year, based on Michigan's 1971 record and the average of three years of Texas data, is 78. The entire U.S. population is approximately 200,000,000, or 10 times that of Michigan and Texas combined. From this one might conclude that, nationally, parked car fatal accidents average 780, or 1.4% of all fatal accidents.



NATIONWIDE, ALL FATALITIES

<u>NATIONAL PROJECTION</u>

FIGURE 10.2-1

Other factors contributing to accidents involving parked cars include roadway and lighting conditions, alcohol impairment, and injury causation,just as in all other accidents. Figure 10.2-2 compares injury-producing parked car accidents and other types of accidents versus roadway conditions,as indicated in the Washtenaw County Accident File for 1971. Icy roadway conditions are more strongly associated with parked car accidents in these data.

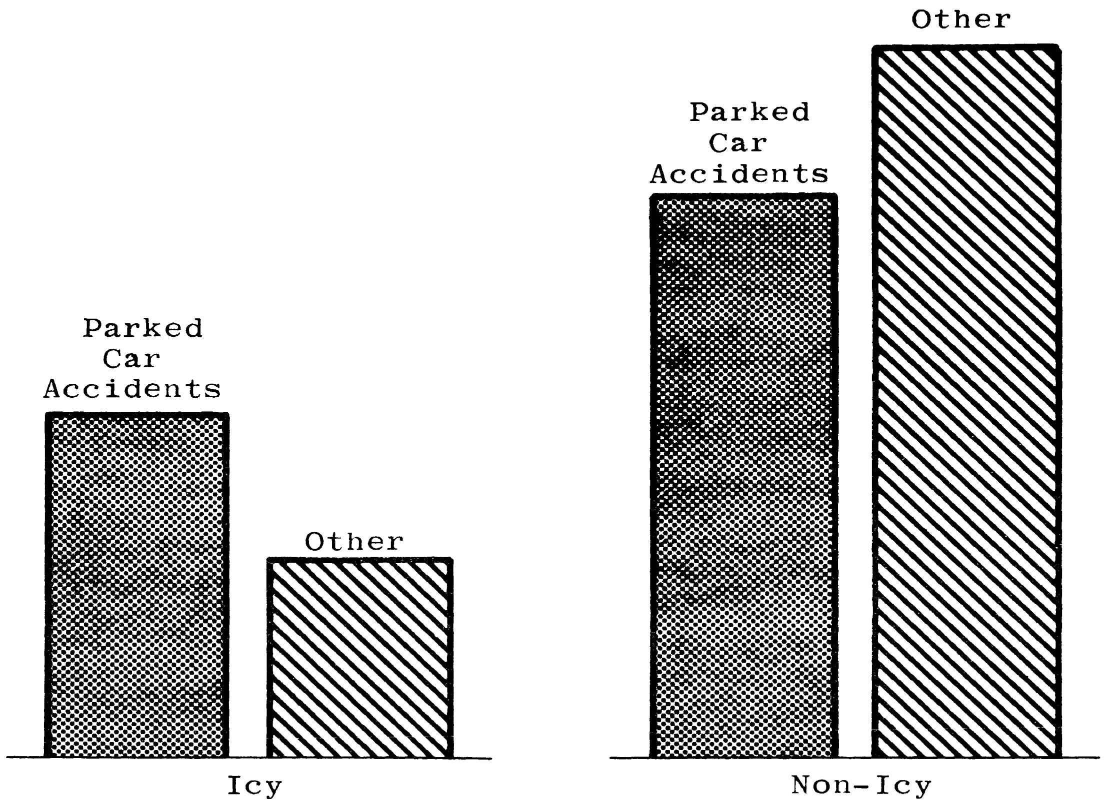
Similarly,Figure 10.2-3 compares the incidence of parked car accidents at night versus daylight, based on a Texas 5% accident sample, and indicates over involvement at night. There appears to be a greater tendency to strike parked cars at night because of restricted nighttime visibility,rather than because of excess of parked cars at night.

The Washtenaw County Accident Data File was reviewed to compare alcohol involvement in parked car accidents with all other county accidents. As Figure 10.2-4 indicates it is not significantly different from its proportion in other accidents, if police reported accident information is reliable. It appears that drivers who strike parked cars are no less alert than the "average" accident involved driver.

Figure 10.2-5 compares injury production of parked car accidents with that of all accidents, based on a Texas 5% sample accident file, and shows that in general, parked car accidents are less serious for vehicle occupants than for those in other type accidents.

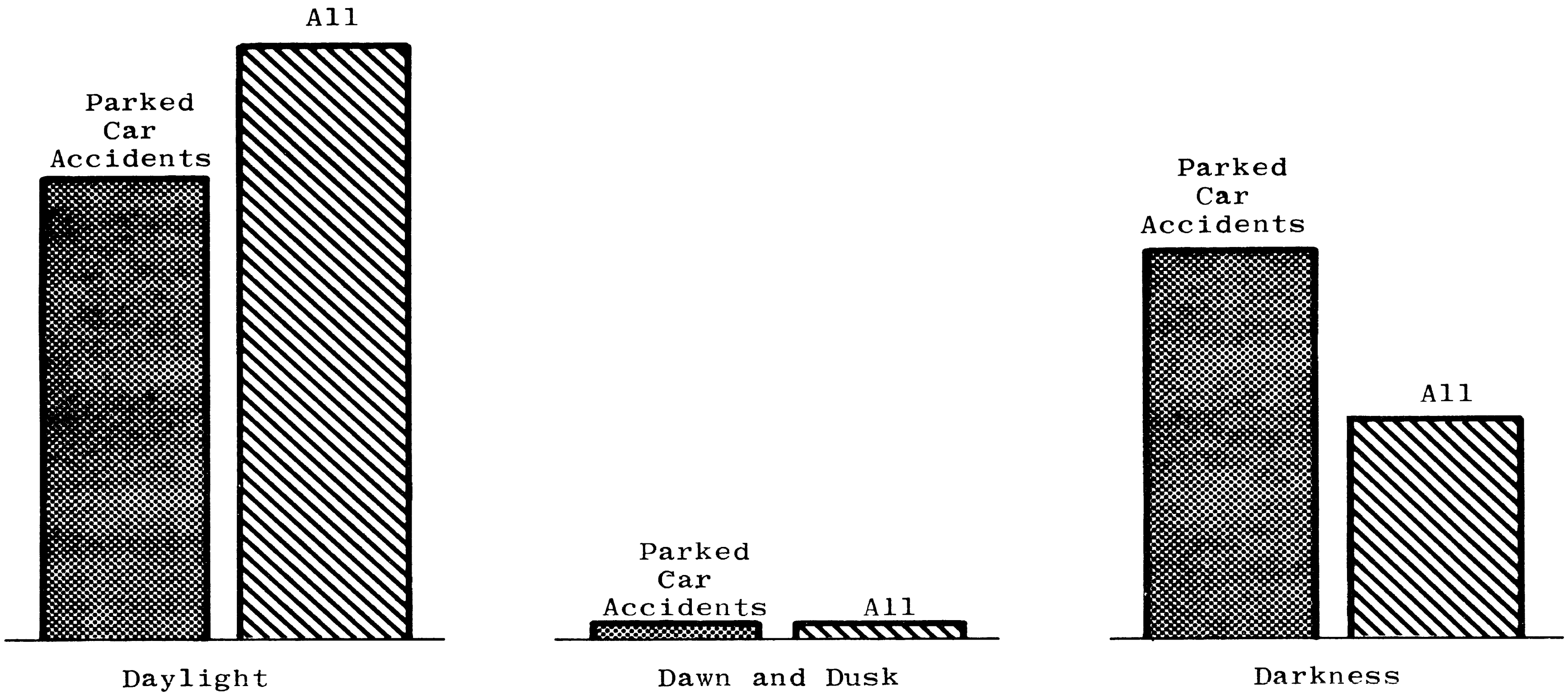
This tri-level assessment of the magnitude of the parked car accident problem should provide initial insight regarding the conditions which precipitate such accidents, the various types of crashes, and the circumstances under which they occur.

In summary, there are a large number of minor parked car accidents each year (approximately 10% of all accidents). Within this group, however, is a segment which constitutes the more severe type crashes occurring on open and limited access highways. This



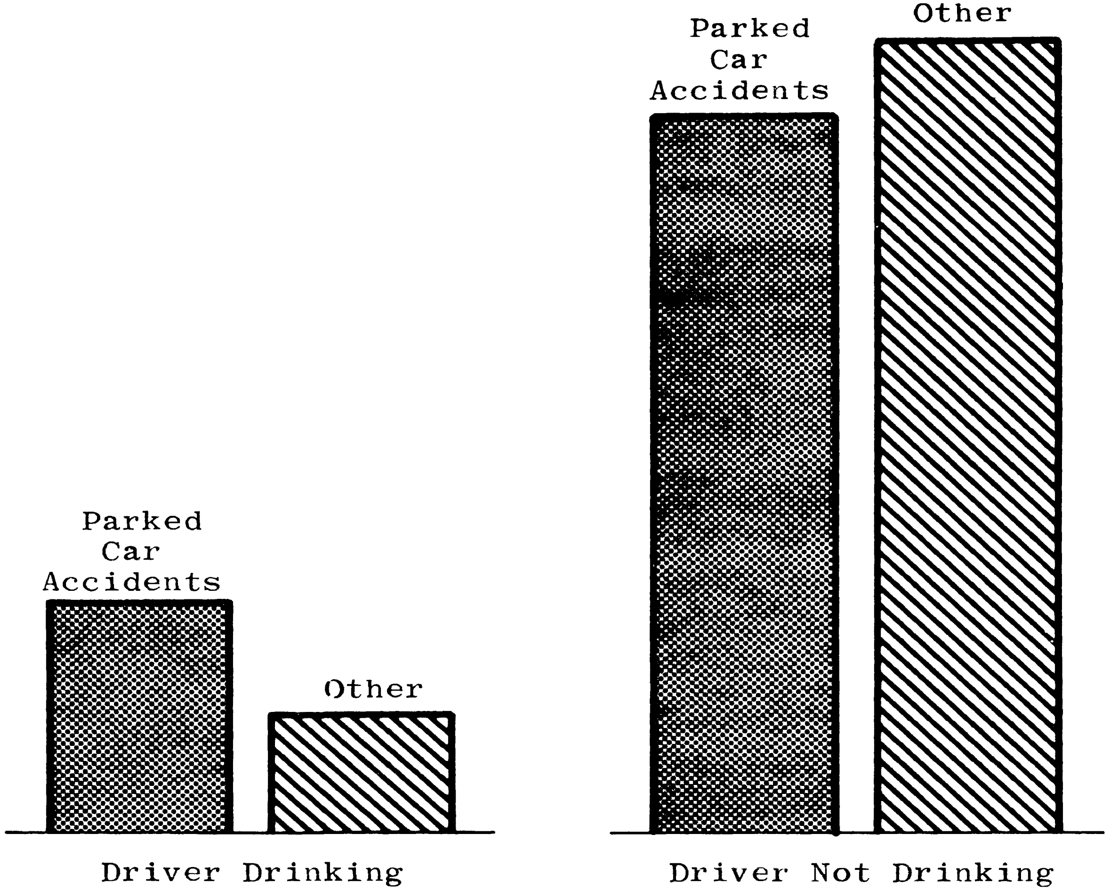
ROADWAY CONDITIONS

FIGURE 10.2-2



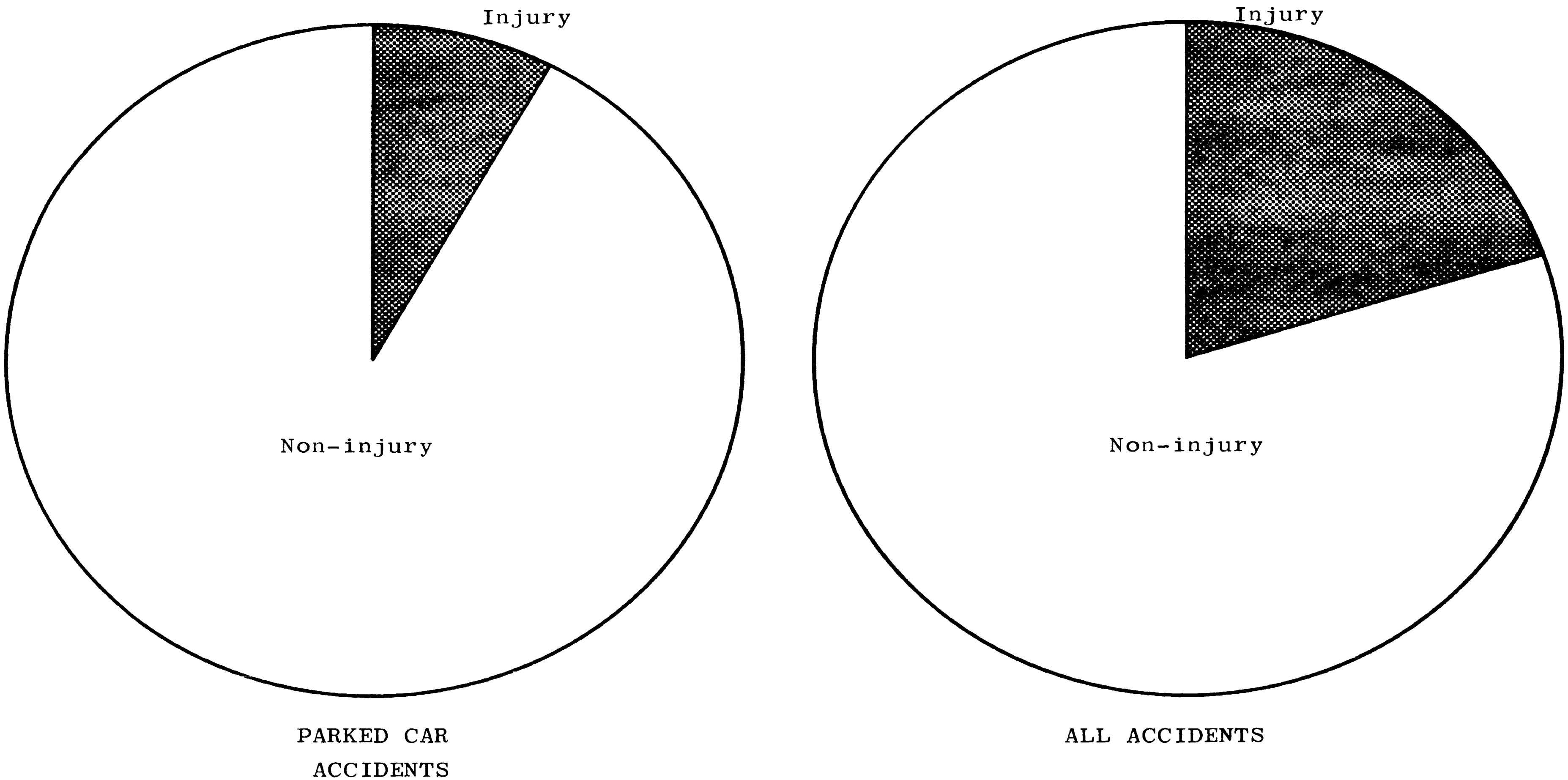
LIGHTING CONDITIONS

FIGURE 10.2-3



DRINKING INVOLVEMENT

FIGURE 10.2-4



COMPARATIVE INJURY PRODUCTION

FIGURE 10.2-5

group appears to account for 1.4% of the national fatality total. The most frequently stated reason for a car being stopped or parked on limited access highways in Washtenaw County, Michigan, is "previous accident", emphasizing the problem of accidents which could precipitate other accidents, and validates Highway Safety Program Standard 16, titled "Debris Hazard Control and Cleanup,"*

Icy road conditions on major highways are more associated with parked car accidents than with all other accidents. Parked car accidents occur most frequently under nighttime conditions. However, alcohol involvement proportionately, is no different than in other accidents.

A suggested countermeasure to reduce parked car accidents, is the use of warning devices, such as portable signs, flashers, and flares, on vehicles parked along the highway. However effective this might be in some situations, it would not have prevented two of the three accidents described earlier. In the accident in which the police patrol car was struck, what could have been better warning than its red flashing lights. A previous accident on the roadway, cited as the reason for most parked car accidents in Washtenaw County, Michigan, may nullify timely use of a warning device to prevent a second accident. Fast police action at the accident site**, including setting up emergency lights, flares, and positioning police vehicles far enough away from the accident site to warn on-coming traffic, seems the best solution.

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* This standard requires that each state have a program for the prompt correction of conditions or incidents that constitute potential dangers on highways.

** Also an objective of Highway Safety Program Standard 15, titled "Police Traffic Services".

10.3 Side Impact Performance

Side impacts, or classic "T" orientation crashes at intersections, constitute a significant portion of all accidents. In Washtenaw County, 10,207 accidents were classed as intersection collisions.* Of 50 Level III accident case studies 20, or 40%, (10 right side and 10 left side) were side impacts.

Vehicles equipped with so called "side guard beam" structures,** or not so equipped, were adequately represented in Level III in-depth case studies. Although the angle and location of the side impact and the impact velocity of the striking vehicle varied, no noticable difference in injury production or vehicle damage severity was observed between vehicles equipped with a "side guard beam" and those not so equipped.

Figures 10.3-1, 10.3-2, 10.3-3, 10.3-4, 10.3-5 and 10.3-6 illustrate several side impact collisions in which the struck vehicle was equipped with a "side guard beam". In Figure 10.3-1, a 1971 Ford Galaxie sustained a perpendicular impact by a 1971 full size Mercury at impact velocity of 30 mph. Sheet metal crush measured 29 inches at the rear surface of the front door. In this accident, the unrestrained struck vehicle driver received minor injuries, but the lap belted right front male passenger, aged 22, sustained wrist and elbow fractures, a rib fracture, liver damage, and spleen and intestinal rupture from the impinging door (AIS-04, serious).***

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* The total number of accidents during this period were 30,577, thus intersection collisions accounted for one-third of all reported accidents.

** Motor Vehicle Program Standard No. 214, titled "Side Door Strength" became effective for all passenger cars manufactured after January 1, 1973. Various vehicle models were, however, equipped with this feature as early as 1969. The standard requires that the structural design of vehicles be such as to meet test requirements for a specified type of force applied to the doors of the vehicle. This is to minimize the injury hazard to occupants in a vehicle struck in the side from intrusion into the passenger compartment by the striking vehicle.

*** American Medical Association Abbreviated Injury Scale (AIS).

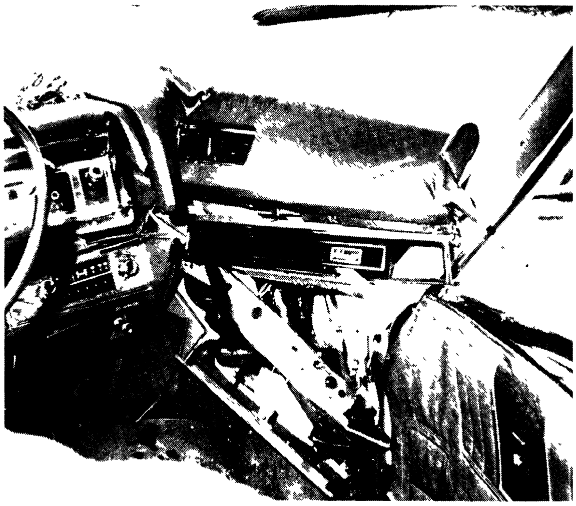

Figure 10.3-2. 1971 Chevrolet Vega

Figure 10.3-2. 1971 Chevrolet Vega

Figure 10.3-3. 1973 Ford Pinto

Figure 10.3-4. 1969 Chevrolet Impala

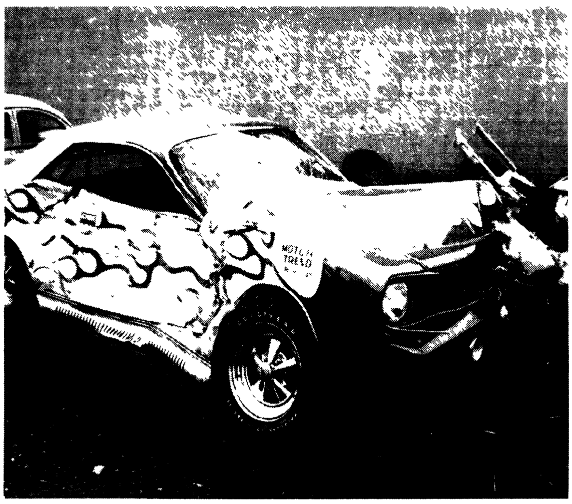

Figure 10 3-5 1970 Plymouth Barracuda

Figure 10 3-6 1972 Plymouth Grand Coupe

The 1971 sub-compact Chevrolet Vega in Figure 10.3-2 was also equipped with "side guard beams", and was struck broadside at 10 mph impact velocity by a Chevrolet pickup truck. Maximum crush was 13 inches at the B-pillar. The driver and right front passenger, both unrestrained, sustained minor injuries. The right rear unrestrained passenger received a severe concussion from contact with the B pillar (AIS-05, critical, survival uncertain).

Figure 10.3-3 shows a less frequent small-car-to-small-car side impact. The 1973 Ford Pinto Runabout with "side guard beams" was struck obliquely by a 1972 Dodge Colt at impact velocity of 20 to 25 mph. Maximum crush sustained was 19 inches. The unrestrained right front female passenger, aged 35, succumbed to multiple trauma. Critical injuries sustained from the side impact included a ruptured liver and spleed and crushed brain stem. Other occupants sustained minor to moderate injuries.

A 50 year old male driver in a 1969 Chevrolet struck by a diesel freight train at 10 mph was unrestrained and received minor bruises. In this accident, the reinforced door structure is credited with significantly reducing side intrusion, as can be observed in Figure 10.3-4. The occupants of the 1970 Plymouth Barracuda in Figure 10.3-5 received minor injuries. The vehicle sustained 19 inches of crush at the A-pillar when struck obliquely by a full size 1969 Pontiac with a velocity of 15 mph.

The 1972 Plymouth Grand Coupe in Figure 10.3-6 was not equipped with any additional door structure. When struck by a 1971 Pontiac moving at 15 mph, it sustained 11 inches of sheet metal crush. The unrestrained 62 year old driver sustained rib fractures from contact with the door and a critical laceration of the aorta (AIS-05, critical, survival uncertain).

A HSRI statistical analysis* of accident data on the performance of "side guard beam" structures in side impact accidents compared injury levels of occupants in cars equipped with "side

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* HSRI Report compiled separately titled, "An Evaluation of the Effectiveness of Side-Door Beams Based on Accident Experience", F. Preston and R. Shortridge is currently in preparation.

guard beams" with those in cars not so equipped. The influence of impact speed, occupant seat location, and restraint use were included in the analysis. A separate comparison was made of the degree of penetration of the striking vehicle into the struck vehicle in the two groups. Again, consideration was given to angle of impact and total energy of impact.

HSRI accident data files for Denver County, Colorado, the Collision Performance and Injury Report (CPIR) file, which includes all HSRI Level III and Level II accident cases, and a 5% random sample of Texas accidents were utilized. These data sets do not represent random or identical samples nationwide so they were analyzed separately as three discrete accident data files. Presumably, if "side guard beams" had a decided effect on injury reduction, this effect would be observed in each of the data files utilized. Analysis precision was limited by the relatively fewer cases involving vehicles with "side guard beams". Because of their relatively recent introduction into late model vehicles , time is required before such equipped vehicles are a significant part of the total vehicle population.

The frequency of side impact collisions was measured by examining the number of vehicles sustaining front door damage in broadside and sideswipe accident configurations, which were a sizable proportion (12%) of all accidents. Left and right front door impacts were equally divided. The effect of seat belt and upper torso restraint use on driver-only injuries was examined. (More information was available on drivers than on right front passengers). The analysis indicated that unrestrained drivers in side impacts were about twice as likely to sustain severe injury as were restrained drivers.

To examine the effect of "side guard beams" on injury, the overall injury severity sustained by drivers of vehicles equipped with "side guard beams" was compared with the overall injury severity recorded for those drivers of vehicles lacking "side guard beams".

The number of accident cases available for this analysis was 196.* While the mean injury value for drivers in vehicles with "side guard beams" was greater than those in vehicles lacking "side guard beams", the difference was not statistically significant.

This analysis indicated that there was no discernable difference at this time between injury severity patterns of occupants in "side guard beam" equipped vehicles, and occupants of vehicles without them. Also, there was no evidence that "side guard beams" reduced overall sheet metal crush in side impact collisions, which allows two conclusions: either they are not effective, or there is not presently enough data to confirm how effective they may be. The effect of "side guard beams" in reducing injury has not been adequately demonstrated by available data. It now seems that any real positive effect must be small. We need more information, best derived from more carefully prepared accident reports.

10.4 Capri Windshields

In accident case study AA 325, a 1972 Capri, 2-door sedan left the roadway out of control and struck a large tree head-on. The occupants sustained injuries and the driver was alcohol impaired, but the most significant finding was that the vehicle windshield bond had completely separated. Vehicle damage, including windshield separation, was similar to that which occurred in a 1971 Opel sedan.** The Opel model in that older case study at the time was under recall for windshield retention design modification in compliance with Motor Vehicle Program Standard (MVPS) #212.

The aforementioned 1972 Capri sustained frontal damage to hood, grill, and bumper with inward crush measuring 16 inches, as shown in Figure 10.4-1. The force of the impact was concentrated

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* CPIR Revision 3 data file for drivers of 1969-73 model vehicles.

** Accident case study AA 154, dated January 26, 1973.

Figure 10.4-1: Capri with 100% bond separation of windshield. (AA 325.)

at the vehicle's longitudinal centerline. Estimated impact speed, based primarily on damage sustained, was approximately 15 mph.

MVPS #212, Windshield Mounting, prescribes that vehicle windshield retention design ensures that occupants in a collision vehicle are contained within the confines of the passenger compartment and not ejected. The 100% bond separation in the 1972 Capri resulted in the windshield becoming completely separated from the windshield opening and falling, intact, on the hood. To determine compliance with the standard, a vehicle is subjected to a longitudinal barrier collision at 30 mph impact. The windshield mounting must retain at least 75% of the windshield periphery, or 50% of that portion of the windshield periphery on each side of the vehicle longitudinal centerline, when an unrestrained, 95th percentile adult male manikin is seated in each outboard front seating position. Considering the large diameter tree which was struck at an estimated speed of 15 mph, it is doubtful that this particular Capri would have passed the tests required of this standard. The windshield of the Capri was cracked as the result of head contact by both front seat occupants, indicating that the force which produced windshield bond separation was due to the collision augmented by secondary interior impact of the front seat occupants.

This accident, and its similarity to the accident involving the Opel, instigated a review of the Collision Performance and Injury Report File for damage to Capris in other accidents. The file contained a total of twenty (about 0.6%) accidents involving Capris. Table 10.4-2 is a tabulation by accident investigating team, windshield damage and contact, the object hit, impact speed, impact angle, and the resultant vehicle damage as measured by sheet metal crush. Of these twenty Capris, six (30%) sustained windshield bond separation. One 1972 Capri sustained 100% windshield bond separation, resulting in complete driver ejection through the windshield opening.

Table 10.4-2 CPIR Data File Capri Accidents

	No	Team	Capri		Windshield Variables					Object Hit	Impact Speed (mph)	Impact Angle (o'clock)	Crush (in.)
			Case	Other	Cracked	Broken	Occupant Contact	Cracked or Broken Occupant Contact	Bond Separation				
	1	CAL	X					?		Auto	5	11	
	2	CAL		X				?		Auto	15	1	18
*	3	CAL	X		X	X	X	X	X	Auto	35	10	43
	4	HSRI	X		X		X	X		Guardrail	20	12	9
	5	HSRI		X	X			?		Auto	10	1	8
	6	HSRI	X					?		Auto	10	10	
*	7	HSRI	X		X			?	X	Ditch	40	(RO)	6
*	8	HSRI	X					?	X	Auto	5	10	
	9	HSRI		X				?		Auto	5	7	
	10	HSRI	X					?		Auto	25	12	19
	11	HSRI	X					?		Auto	10	12	6
	12	HSRI	X					?		Sign	?	?	0
	13	HSRI	X					?		Auto	10	10	10
*	14	SW	X		X		X		X	Fence	45	10	16
	15	HSRI	X							?	?	0	1
	16	HSRI	X		X			?		Tree	?	0	7
*	17	HSRI	X		X				X	Guardrail	63	11	8
*	18	HSRI	X		X		X	X	X	Tree	15	12	15
	19	HSRI	X		X		X			Auto	32	12	18
	20	HSRI	X							Auto	12	9	

Table 10.4-3 CPIR Data File Opel Accidents
Windshield Variables

	No.	Team	Cracked	Broken	Occupant Contact	Cracked or Broken Occupant Contact	Bond Separation	Object Hit	Speed (mph)	Impact Angle (o'clock)	Crush (in.)
*	1	HSRI	X				X	Pole/tree	15	1	15
*	2	Baylor	X	X	X	X	X	Vehicle	25	12	16
*	3	CAL	X		X	X	X	Guardrail	15	12	
*	4	CAL	X	X			X	Wall	35		14
*	5	CAL	X	X	X	X	X	Tree	12	12	14
	6	Geo. Inst.						Vehicle	25	1	27
	7	HSRI						Vehicle	5	1	10
	8	HSRI						Vehicle	15	3	
	9	HSRI						Guardrail	55	9	
	10	HSRI						Vehicle	5	12	6
*	11	Maryland	X	X			X	Fence	25		
*	12	Maryland	X				X	Pole/tree	40	8	4
*	13	Maryland	X				X	Pole/tree	35	8	4
	14	New Mexico						Vehicle	55	10	
	15	New Mexico			X			Vehicle	2	2	
	16	HSRI	X		X	X		Vehicle	30	11	26
*	17	HSRI	X	X			X	Vehicle	45	12	22
*	18	HSRI	X	X	X		X	Vehicle	50	11	
	19	Ohio						Vehicle		9	
	20	Rochester	X		X	X		Vehicle	20	11	19
*	21	SWRI	X	X			X	Vehicle	41	12	11
*	22	SWRI	X	X			X	Vehicle	40	10	
*	23	SWRI	X		X	X	X	Pole/tree	15	12	14
*	24	Toronto	X	X	X	X	X	Vehicle	40	12	11
	25	Toronto						Vehicle		5	
*	26	Toronto	X	X			X	Fence	40	1	
*	27	HSRI	X		X		X	Vehicle	28	11	
	28	HSRI						Vehicle	20	12	10
	29	HSRI	X		X	X		Ditch			3
	30	HSRI	X					Guardrail			16
*	31	HSRI	X				X	Vehicle	25	2	23
*	32	HSRI			X		X	Embankment		3	1
	33	HSRI						Guardrail		11	
*	34	HSRI	X				X	Ditch		2	
*	35	HSRI	X		X		X	?	15		
*	36	HSRI	X				X	Vehicle	25		
*	37	HSRI	X				X	Mailbox			
*	38	HSRI			X		X	Wall			2
	39	Okla.						Vehicle	10	12	20
	40	Utah	X		X	X		Vehicle	33	11	

The same CPIR data file was reviewed for accidents involving Opels, as shown in Table 10.4-3. There were 40 accidents involving Opels in the CPIR vehicle file (1.2%). Twenty-three Opels, or about 60% of those involved in accidents, had sustained windshield bond separation, indicating a greater incidence of windshield retention failure in Opels than in Capris. Therefore, although case study AA 325 indicated a potential windshield retention problem with the Capris, the data sets indicate that it may not be as serious as with Opels which were under recall for failure to meet windshield retention standards.

10.5 Maverick Seat Belt

In one multidisciplinary case study fatal accident a 25 year old male driver, although wearing a lap belt, was partially ejected out the left window during a violent rollover.* The vehicle had ran off a four lane divided expressway, struck a guardrail, then went airborne and tumbled end-over-end down a 30 foot embankment, coming to rest on its wheels.

The vehicle and occupant were not discovered until 7½ hours after the crash. The vehicle, a 1972 Ford Maverick Grabber, is shown in Figure 10.5-1. The driver's body, still lap belted, was leaning against the outwardly deformed left front door. His right leg was folded beneath him as shown in Figure 10.5-2. A blood sample analysis indicated a blood alcohol concentration of 0.09%.** During rollover the driver had been partially ejected out the left door side glass opening and contacted the outside upper "A" pillar, windshield, and windshield header area, ten inches to the right of the left "A" pillar.

For the driver to have been so partially ejected while lap belted, the seat belt must have fully extended during the violent rollover.

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* Case study AA 328, "Passenger Car/Rollover", December 11, 1972.

** Percent weight by blood volume.

Figure 10.5-1: Final resting position of maverick. (AA 328.)

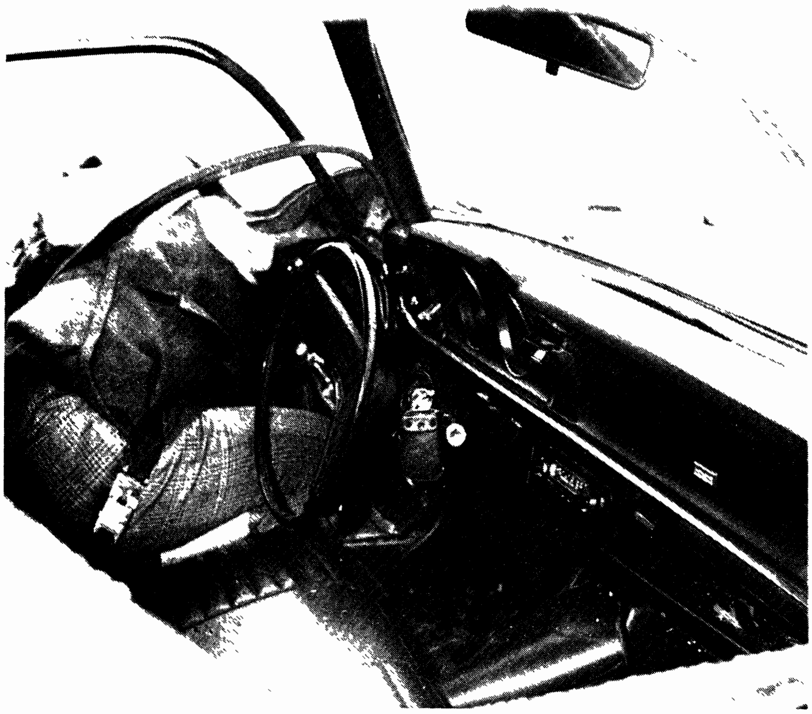

Figure 10.5-2 Deceased belted driver of case AA 328 in final resting place.

The lap belt and locking retractor were removed from the vehicle for study and evaluation.

The seat belt locking retractor design has a reel with detents along both outside edges and a locking bar parallel to the reel, as shown in Figure 10.5-3. The ends of the locking bar extend past the reel, which causes the bar to engage the detents and lock the reel, preventing further rotation. The locking bar is under spring tension to insure that it engaged the detent. The primary force holding the locking bar in place, however, is provided by the engaged detents while the lap belt is under tension.

Apparently, as the driver was thrown back into his seat during rollover, tension lessened on the belt, causing a relaxing of the applied force between the locking bar and the engaged reel edge detents, resulting in a release of the locking retractor mechanism. The force orientation was the same as required to overcome the spring on the locking bar. If these events occur simultaneously, the belt is free to unwind its entire length. Fully extended, the slackened belt allowed the driver to become partially ejected and strike his head on the exterior surface of the windshield.

A second possible series of events that would have enabled the locking retractor to release and permit the belt to unwind involves the plastic housing, or "boot," surrounding the retractor reel mechanism. This housing was fractured during the crash, making it possible for the belt to slip partially off the reel laterally, come into contact with the locking bar, and force the locking bar up so as to become disengaged from the detents on the reel. This would allow the belt to unwind. The belt, displaced laterally from the reel, is shown in Figure 10.5-4. This would not be possible if the belt were always aligned properly with the reel. This is the function of the "boot" on the plastic retractor mechanism housing.

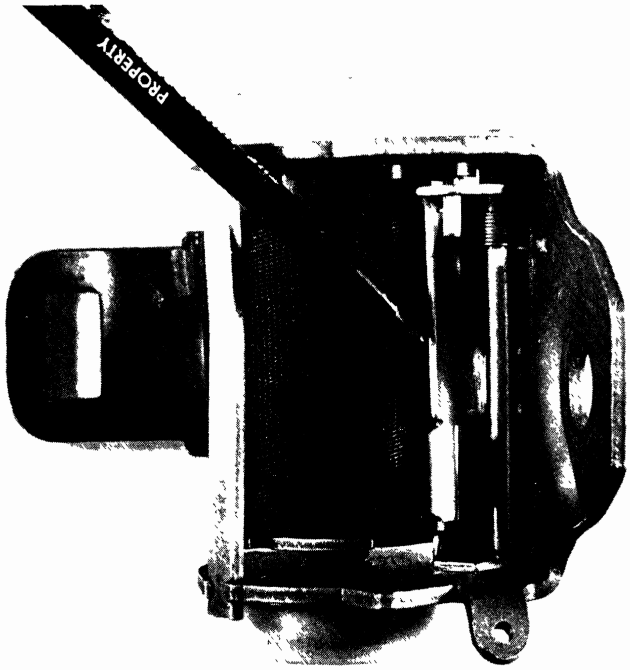

Figure 10.5-3. John Robbins Co. locking retractor. Pen points to locking bar.

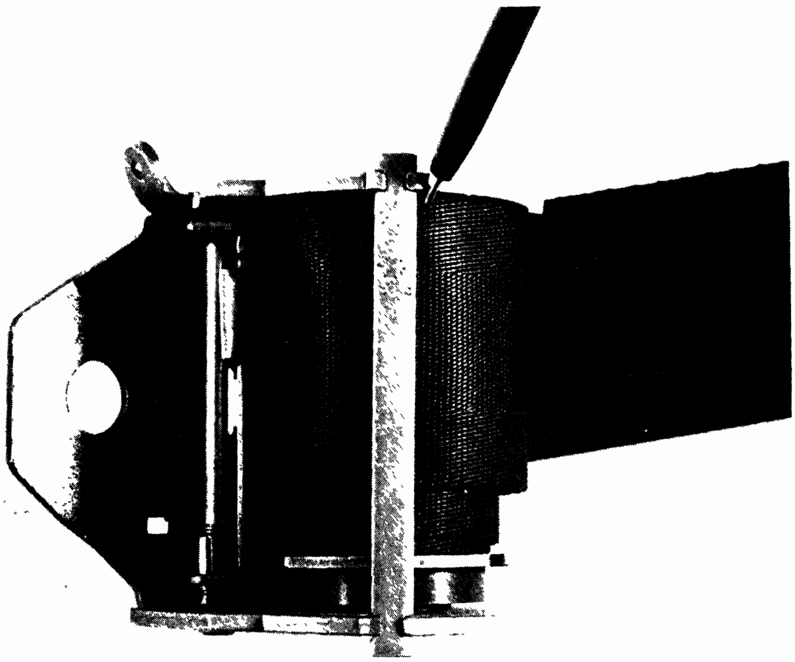

Figure 10.5-4. Belt displaced laterally across reel end inhibiting the locking bar from engaging the reel end detents.

To inhibit the belt from slipping off the reel, it is recommended that a metal guide be included as an integral part of the retractor design so that the belt is always constrained to proper alignment with the reel.

The locking retractor used in the case vehicle was manufactured by the Jim Robbins Seat Belt Company. For comparison, the design of other seat belt and retractor assemblies, such as those manufactured by Hamill Manufacturing Company, (see Figure 10.5-5) and General Safety (see Figure 10.5-6), were examined. These units use the same principle in design and could also release in a similar crash situation as described in case study AA 328.

HSRI has not observed a comparable case wherein a seat belt released, either in a collision studied or in a controlled sled test, but the violent rollover accident described indicates a need for improvement in present locking retractor designs. Present tests for compliance with Motor Vehicle Program Standards* use simulated head-on, barrier type, crashes but no other crash orientations.

10.6 Multipurpose Vehicles

Three multidisciplinary accident case studies completed during the past year involved multipurpose vehicles. Such vehicles are increasing in popularity, and yet are of growing concern in terms of their overall safety. The multipurpose vehicle category includes "Jeep" type vehicles, snowmobiles, motor homes, truck campers, camper trailers, car top campers, dune buggies, and sports cycles. Three vehicles examined extensively by the HSRI team as three different Level III accident case studies were a Jeep postal service vehicle, a Ford Bronco, and a Swinger Statesman 28 foot motor home.

The driver of the 1970 Jeep postal service delivery vehicle,** a 27 year old male, ran a red traffic signal in the central city

* MVPS #209, Seat Belt Assemblies - Passenger Cars, MPV, Trucks and Buses. The method of testing automatic locking retractors is by simulation of head-on collisions only, which are conducted exclusive of gravitational forces such as those found in a rollover crash.

** Case AA 301

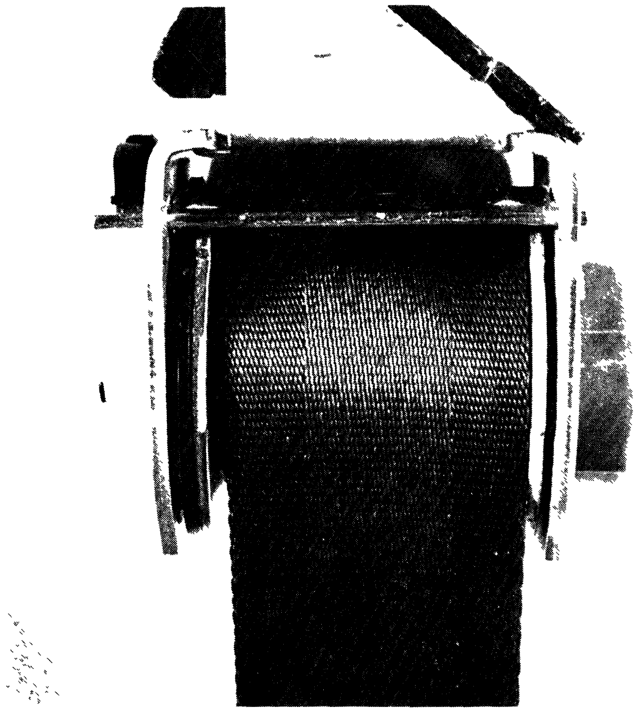

Figure 10.5-5. Locking retractor manufactured by General Safety.

Figure 10.5-6. Locking retractor manufactured by Hamill Co., showing locking bar.

area of Ann Arbor, Michigan, and was struck by a 1963 Valiant Convertible. Upon initial impact, the postal service Jeep went into reverse, backed the distance of an entire city block, and rear-ended a luminaire pole. The Jeep had been manufactured to post office specifications and lacked many safety features required of present passenger cars. The rather harsh interior had no instrument panel padding design and offered little occupant protection.

A 1972 Ford Bronco in case study AA-332 struck a guardrail type median barrier on an elevated concrete median, as shown in Figure 10.6-1. The Bronco vaulted the guardrail, went across opposing traffic lanes out of control, and executed a $1\frac{1}{4}$ roll in the fill section adjacent to the roadway. The driver was ejected out of the left side glass opening, and the vehicle rolled over him, causing fatal injuries. The vehicle's high ground clearance and high center of gravity facilitated its vaulting the median barrier and rolling over. The driver had owned the vehicle one week. Unfamiliarity with the handling characteristics of such a vehicle may have contributed to loss of control.

The driver of the 1973 Swinger Statesman 28 foot motor home had passed from a curve to an ice covered tangent section of interstate highway, whereupon the vehicle began to skid. He overcorrected the skidding vehicle, fishtailed under marginal control into the inside lane, then attempted to return to the outside lane. As the vehicle slid sideways onto the outside lane he steered right in an attempt to straighten out, but he lost control. The motor home then rotated clockwise across both lanes onto the median, overturned in a three-quarter roll, and burst into flames when fuel which had leaked from its tank ignited. The vehicle was totally destroyed by the fire as shown in Figure 10.6-2. The driver was able to exit uninjured before fire completely enveloped the vehicle. The driver was familiar with this amke and model of vehicle but had driven this particular one only 350 miles.

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* Case AA 338

Because of limited data on the frequency of recreational vehicle accidents, it can only be assumed that some inherent problems relative to safety exist in recreational vehicles.

There are no special recreation vehicle driver requirements, such as proven experience and/or demonstration of operator skills. Some pickup campers and larger motor homes are even more difficult to control than large commercial trucks. Drivers familiar only with passenger cars have adjustments to make when they get behind the wheel of a multi-purpose vehicle. The required turning, braking and transmission shifting efforts normally are different. There is reduced rearward visibility. Greater space is needed for simple turning maneuvers.

In handling and control, acceleration and stopping distances may differ from those of regular passenger cars on the same highway. The dynamic stability of many multipurpose vehicles, especially pickup campers and motor homes,can be unpredictable especially if they are overloaded.

Both the Bronco and Swinger Motor Home accidents were "loss of control" type crashes. The Bronco accident also illustrates how multipurpose vehicles,like many trucks, may not fully match with highways designed primarily for passenger cars. The Bronco's high ground clearance increased its chances of vaulting the median barrier after striking the median curb. The Swinger motor home accident highlights the limited structural integrity of many motor homes. Most consist of box-like skeletons of metal framework with thin outer and inner skins attached. These structures are poorly designed to encounter the forces involved in crashes, especially rollovers, so the injury potential for passengers is considerable. The insulation material in motor homes, although fire retardant, once ignited, burns like wood. In the Swinger motor home accident the vehicle was totally destroyed by fire. Many other four wheel drive, all-terrain vehicles have enclosed frame and skin bodies similar to motor homes. So do light pickup canopy covers which provide little protection for occupants, when in collisions or rollovers. MVPS #216 (Effective 8-15-73) which requires that vehicle roofs resist crush applies only to passenger cars at this time. The National Highway Traffic Safety Administration has defined a multipurpose vehicle as: "a vehicle with power, except a trailer, designed to carry ten persons or less, which is constructed either on a truck chassis or with special features for off-road operation". This is a broad definition which makes it difficult to adopt all current motor vehicle standards to vehicles covered so vaguely.

Considering the recreational and multi-purpose use of light trucks ($\frac{1}{2}$ to 3/4 ton classifications), it appears that many current passenger car standards dealing with brakes, tires, interior protection, head restraints, etc., also could be applied effectively to light trucks. At present over 50% of all trucks manufactured are purchased for personal or recreational use.* Not all the vehicles included within the current multipurpose vehicle classification, such as snowmobiles, trail bikes, etc., are able to meet the many standards which apply to passenger cars. It would benefit the buying public if more of these vehicles met consumer-information type requirements.

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* Vehicle manufacturers trade publication.

Figure 10.6-1: Overturned Bronco in the distance and guardrail which the vehicle vaulted in foreground. (AA 332).

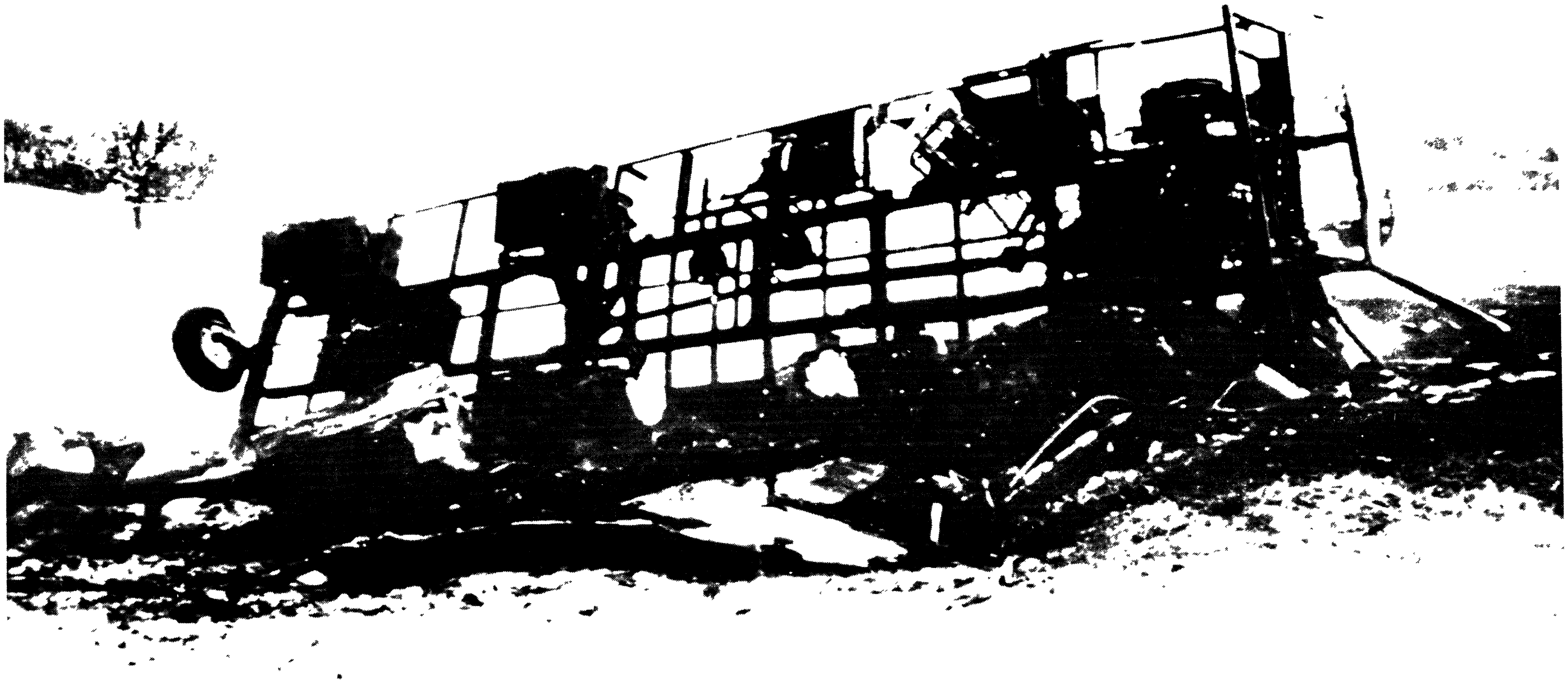

Figure 10.6-2: Overturned and burned Swinger motorhome.
(AA 338.)

10.7 Hood-Windshield Involvement

One multidisciplinary accident case study completed during the year focussed attention on hood-windshield involvement in accidents, and resultant injury to front seated occupants from contact with the hood.

In accident case study AA 330, a passenger car collided with the rear of a truck, resulting in fatal injuries to the right front occupant because the passenger car's hood penetrated the windshield.

This accident occurred Friday, December 29, 1972, at 1905 hours, in heavy traffic and adverse weather on eastbound I-94 south of Ann Arbor, Michigan. The driver of an eastbound truck belonging to the City of Ann Arbor suddenly switched from outside to inside traffic lanes with the intention of making an illegal U-turn on the divided highway median, and entered the path of a 1971 Cadillac 2-door Coupe de Ville which was proceeding in the inside eastbound lane at an estimated speed of 65 mph. The truck, purchased as U.S. Government surplus property, was a 1952 GMC M135 $2\frac{1}{2}$ ton, 6x6 type of military design. The Cadillac driver, who had just passed two other vehicles which were following the truck in the outside lane, was unable to stop and swerved toward the median but crashed into the left rear dual wheels of the truck. This resulted in a 22 inch over-lap between the Cadillac front and truck rear bed, which was also equal in height above the roadway with the Cadillac hood.

Upon impact, the Cadillac hood crumpled and sliced rearward with its right rear edge penetrating the windshield. The right front passenger in the Cadillac, the 55 year old wife of the driver, was wearing a lap belt but without the upper torso restraint. She moved forward on impact and contacted the rearward moving, penetrating hood edge, and sustained fatal injuries directly to front center of her head. (See Figure 10.7-1).

Contributing factors to the accident were: (1) the limited visibility due to darkness, mist and heavy rain, compounded by inadequate rear lighting on the truck. The truck had been poorly maintained by the city with but one taillight operative, and it was not registered for highway travel because it was used mainly for snow removal at the city's airport; (2) the probability that the Cadillac driver was travelling too fast for prevailing conditions when passing. He had a record of speeding violations and, at one time, had a high risk insurance rating.

The Cadillac hood was of the "hidden" wiper or recessed wiper design. It was the override of the truck bed at the vehicle's left rear that first contacted the Cadillac hood, resulting in hood separation at the first latch and rear hinges. Figure 10.7-1 shows the windshield area contacted by the hood. Had the Cadillac driver fortuitiously not swerved and, instead, struck the truck driectly in the rear, there would have been no underriding, because the truck's frame extended almost flush with the rear end of the truck bed, to the extent of encompassing the coupling hitch used for towing military trailers and artillery pieces.

Hood involvement with windshields has been the subject of a separate study, utilizing tri-level data available from Washtenaw County as well as other data sources. The single accident data source in which sufficient detail is present to identify hood contact, or penetration, is the CPIR data file. There is current information in the Washtenaw County file on tow-away involvements of relatively new American-manufactured cars over a period of 20 months. Washtenaw County police mass accident data (Level I) was also examined in conjunction with the CPIR file to estimate the general frequency of hood windshield involvement.

Within the Washtenaw County subset of the CPIR data file, hood contact with the vehicle's windshield occurs in about 4% of the cases. Given hood-windshield penetration, nearly 14% of the occupant injuries were associated with the hood, with 8% unequivocally attributed to the hood. Injuries associated with occupant contact with displaced hoods were usually severe. However, it should be noted also that the crashes themselves also were severe.

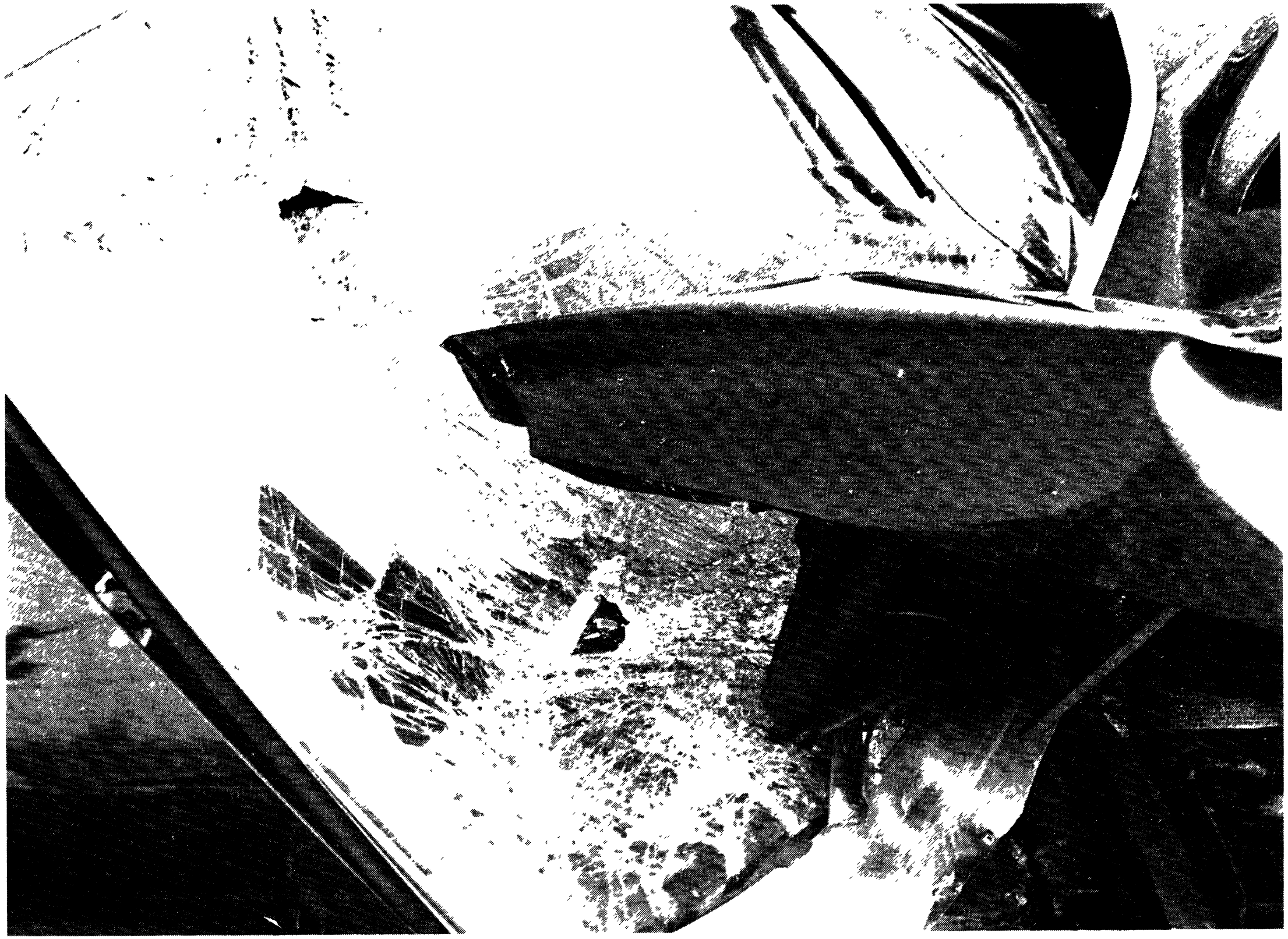

Figure 10.7-1: 1971 Cadillac with windshield penetrated by hood after rearending truck. (AA 330.)

Washtenaw County police mass accident data, in conjunction with the CPIR data, indicates that hood-windshield penetration may result in about 0.8% of reported accidents, based on the reporting criterion* presently in force in the State of Michigan.

A significant increase in hood-windshield contact has been noted and associated with the introduction of the so-called "hidden wiper" hoods. However, there has been no accompanying noticable increase in hood-windshield penetration. An increase in penetration associated with early GM models is statistically significant but may be the result of a bias resulting from accident case selection in that time period (1969). It also appears that hood-windshield penetration and serious injuries do not occur in practice at barrier equivalent speeds of less than 30 miles per hour. The accident in case study AA 330 would also support this finding, although the struck barrier in this case study was the truck bed overhang.

We believe that hood design and hood performance during crashes merits further study, with the objective of reducing the incidence of hood-windshield contact and/or penetration. A suggested line of investigation is the adoption of a frangible design for hoods or the use of frangible or yielding materials in hood construction. This, it appears, it a current design practice of some vehicle manufacturers.

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* (At least one injury and/or more than $200 property damage in the accident).

APPENDIX A

A STATISTICAL DESCRIPTION OF LARGE AND SMALL CAR INVOLVEMENT IN ACCIDENTS*

* Presented at the Automotive Safety Seminar, June 20-21, 1973 at the GM Training Center, Warren, Michigan .

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

In vehicular crashes, unrestrained occupants move at the vehicle's speed prior to the event. This often results in a "second collision" between the occupant and the vehicle interior. Injury severity is determined primarily by the force of the interior impact. Collisions between vehicles follow the law of conservation of momentum. Hence, for vehicles of dissimilar weights, the lighter vehicle sustains the more abrupt change of speed. This relationship which is intuitively understood by even the most casual observer of the accident process, arouses concern for small car safety in our present vehicle population. Furthermore, the comparatively smaller interior volume of small cars limits the distance in which passengers sustain the deceleration forces in a crash.

An examination of effects on safety of a changing vehicle size population is timely because of current pressures for change. Cost has long been a factor in size selection, but more recently considerations of fuel consumption and maintenance seem to be influencing buyer decisions. The trend is toward personal rather than family cars, the youth market, the scarcity of parking space, and the easier handling in traffic all promote interest in the small car.

Many previous studies have considered the differences between small and large vehicle in crashes. These have included controlled crashes between dissimilar sized vehicles,[1,2,3] analysis through mechanical models,[4,5] individual accident case investigations[6,7,8] and examinations of mass or police level accident data.[9,10,11,12,13,14,15] Past accident data often does not accurately define just what constitutes a "small car", or fully describe the exposed vehicle population in terms of size. In general, however, these studies support the intuitive conclusions discussed earlier, that the risk of injury for smaller car occupants is greater, that small cars are overrepresented in single vehicle accidents, that they are driven by younger drivers, and that they contain comparatively fewer occupants.

The present study is based on a variety of data sources, and in general confirms the above conclusions. It also attempts to quantify the risk of injury to occupants of small and large cars in various accident configurations, and to thus predict injury rates as a function of change in the size-mix of the vehicle population.

Washtenaw County, Michigan represents the primary data sources used for this study. Data include a digital file of police accident reports* augmented with vehicle licensing weight information (derived from the Michigan Secretary of State

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*This file is a subset of the file of Washtenaw County accidents maintained by HSRI, and contains 16,360 passenger cars in accidents during the period 1968-1970.

registration records). a sample of driver records* for this county, and a sample of vehicle registration** records for the same area.

Accident data was used to determine general characteristics of the cars, their drivers, and to examine various kinds of two-vehicle interactions. Injury information was based on the police coding system. For this study, this data has been reduced to two levels (injured or not injured). The vehicle registration file was used to determine vehicle weight distribution in the general population by model year. The driver record file was used to determine drivers by age, sex, and accident rate.

Two other data files were utilized,--the CPIR-3 accident data file,*** and National Exposure File.**** These provided information relating to restraint system usage, annual mileage, and occupancy (by car size).

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*This is a 10% sample (17,989 drivers) of drivers licensed in Washtenaw County, and contains information on their violation and accident experience.

**This is a 10% sample (11,255 vehicles) of vehicles registered in 1972 in Washtenaw County, and contains information on make, model, and weight.

***This is a file of detailed accident information resulting from MVMA and NHTSA sponsored accident investigation programs.(16) It currently contains detailed information on 3,500 vehicles involved in accidents.

****This file is the result of an exposure survey conducted in 1970 in 18 states and is concerned with driving mileage reported by those interviewed.(17) Comparisons of personal characteristics, vehicle types, and mileage are available.

These data have been developed in part with the support of the Motor Vehicle Manufacturers Association and within the Tri-Level Accident Investigation Study Program* sponsored by the National Highway Traffic Safety Administration. This paper is the result of an analysis of these data under the latter program.

*Contract number DOT-HS-031-2-454.

VEHICLE POPULATION CHARACTERISTICS

The proliferation of smaller cars over the past few years, particularly in the 2000-5000 pound range, has been evident to even the casual observer. In 1969 approximately 8% of the vehicles on the road in the U.S. weighed less than 2500 lbs. In 1972 this had risen to 13%.*

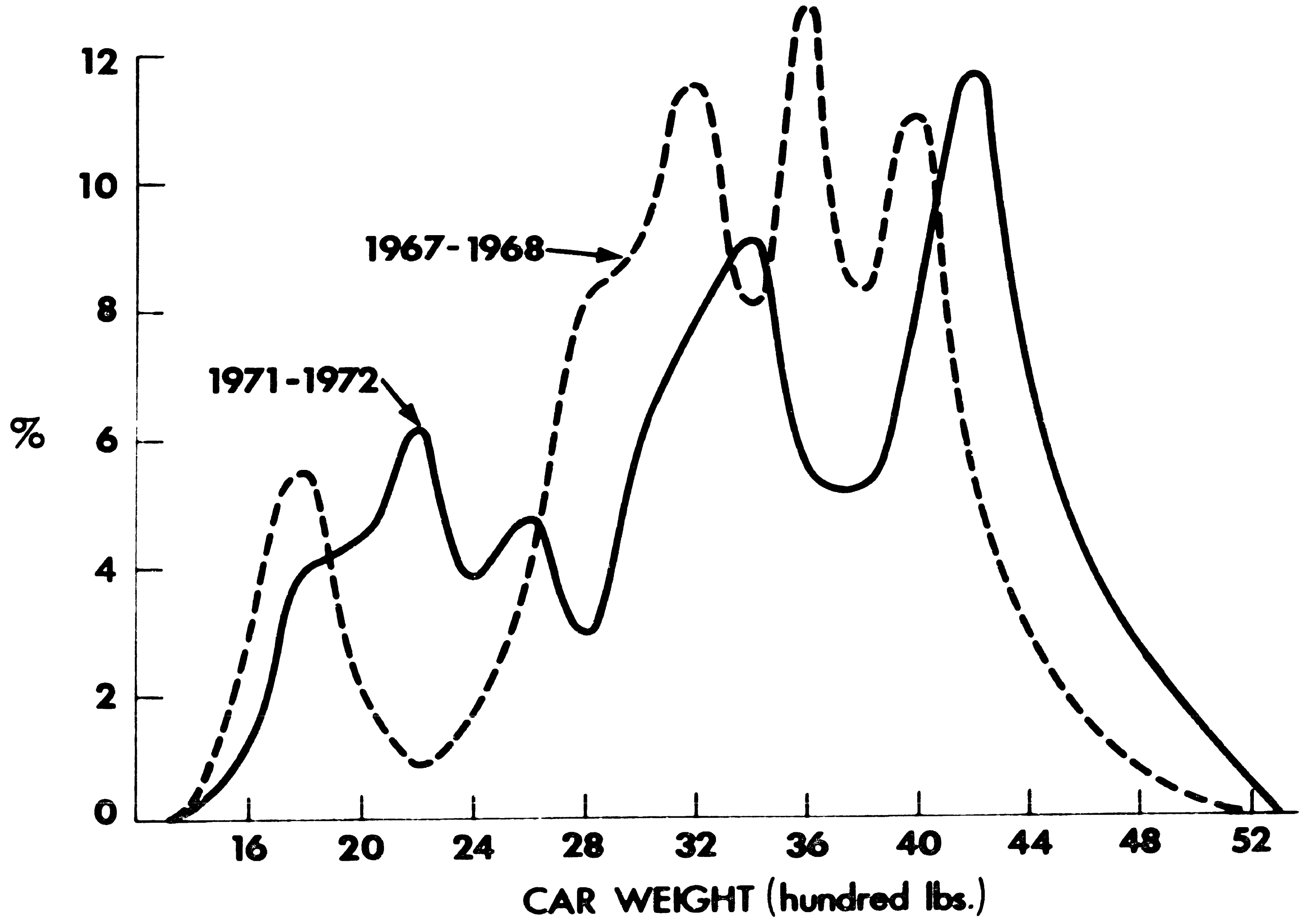
This change is reflected in the Washtenaw County car population as shown in figure 1. The 1967-68 model year vehicles (in 1972) are shown as a dotted line. Note particularly the peak at about 1700 pounds, and then the broad triple peak centered at about 3700 pounds. In the 1971-72 model year in the same population two changes are apparent. The small car weight peak shifted substantially, filling in the void in the 2000-2500 pound range, and the large car peak moved to the right indicating a smaller, but still increasing change in weight.

Mean weight of the registered vehicle population in 1972 is plotted by model year in Figure 2, with a steady increase noted, although there was a slight dip coinciding with the massive introduction of small American cars in 1970-71.

The relatively large change in mean weight of a model year is reflected slowly in the accident year. Figure 3 shows histograms of the weights of vehicles in accidents in Washtenaw County during the calendar years 1969 and 1970, which are

*As tabulated in Automotive News yearly almanac, with quoted source the R.L. Polk Co.

Comparison Of Car Weight Distributions For 1967-1968 And 1971-1972 Model Years



FIGURE

Mean Weight By Model Year

(1972 Washtenaw County Registration File)

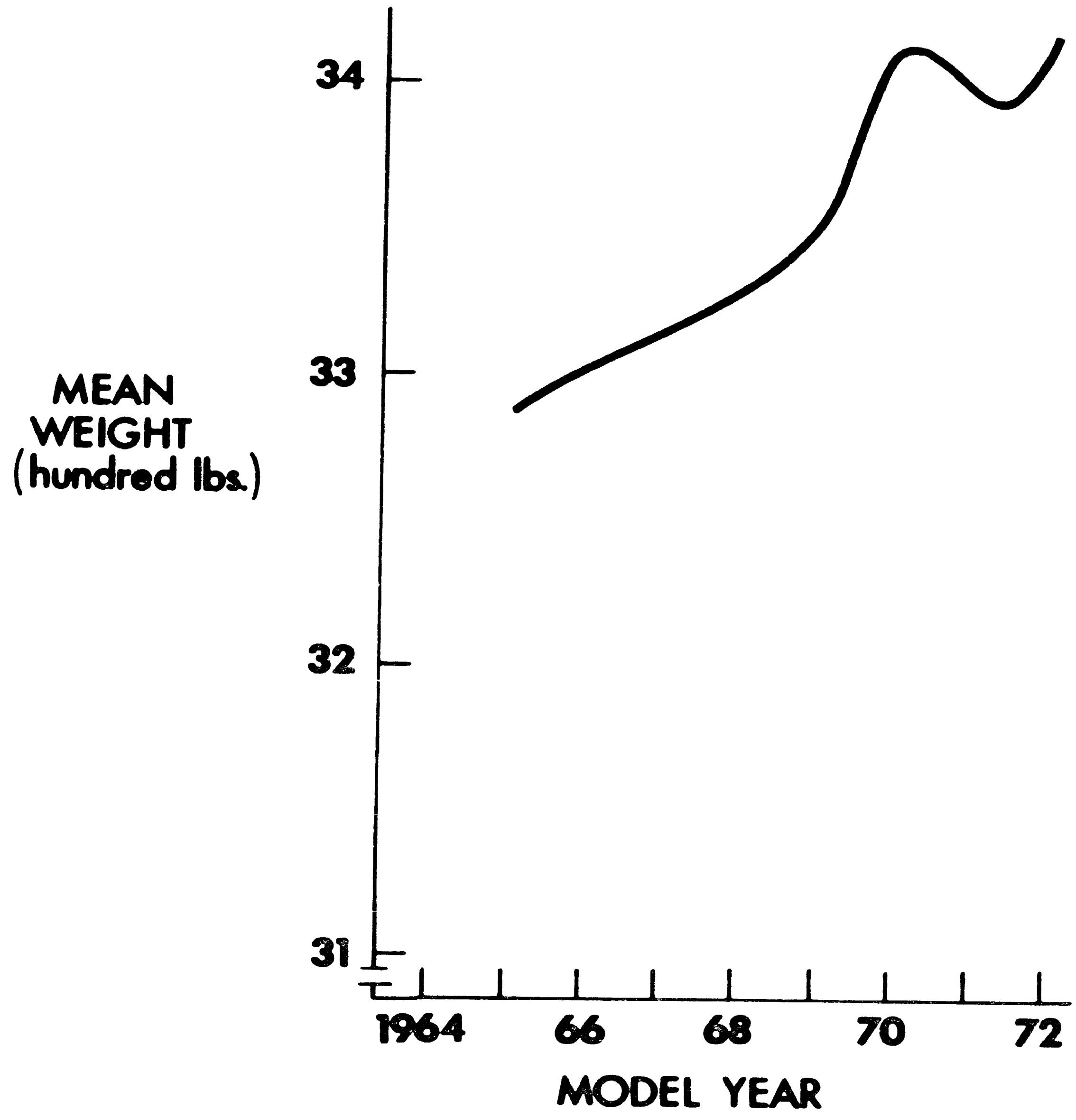


FIGURE 2

Histograms Of Accident Vehicle By Weight For 1969 And 1970

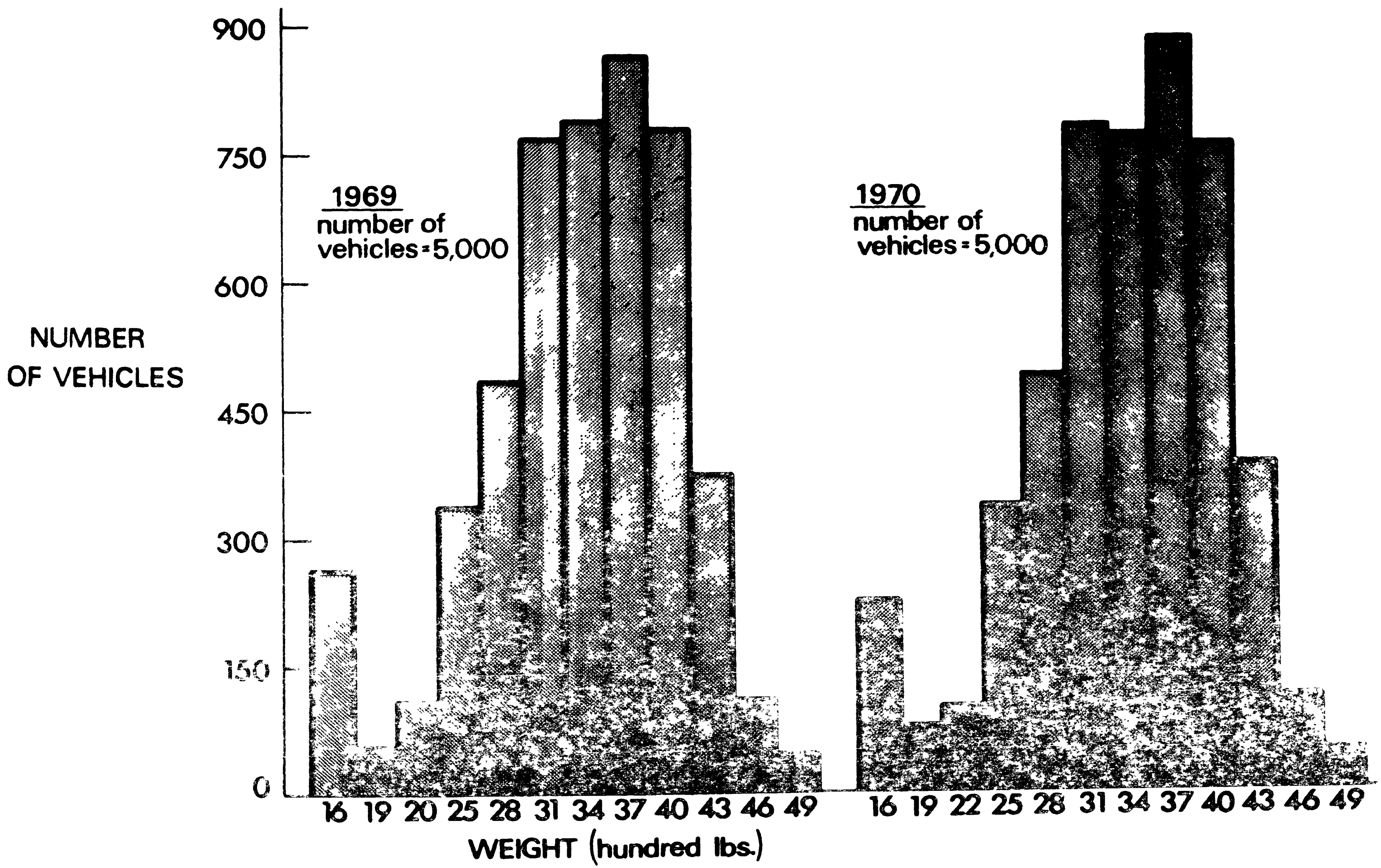


FIGURE 3

substantially identical. But over a span of several years it can be expected that there will be a continuing shift toward the 1971-72 distribution of Figure 1, that is, proceeding from a sort of bimodal distribution to a more rectangular or uniform distribution.

In this study we have somewhat arbitrarily defined small cars as those cars with a licensing weight of 3100 pounds or less, and large cars those with a licensing weight of 3300 pounds or greater. The 200 pound range in the middle of the distribution of Figure 4, then, has been discarded. The use of weight data rather than body style or size was chosen because of some lack of precision in the latter. The CPIR-3 accident data file records both weight and body size (using the usual manufacturer's descriptors), with the relationship between the two illustrated in Figure 5. Note that the heaviest mini-car, and the lightest full-size car, overlap in weight, as do all of the other categories. Small cars, as we have defined them for this study, include essentially all of the mini-cars, nearly all of the compacts, and the lighter half of the intermediates. The large car group includes the remaining half of the intermediates, and all full-size vehicles.

Histogram Of All Vehicles Registered In Washtenaw County For 1972 By Weight

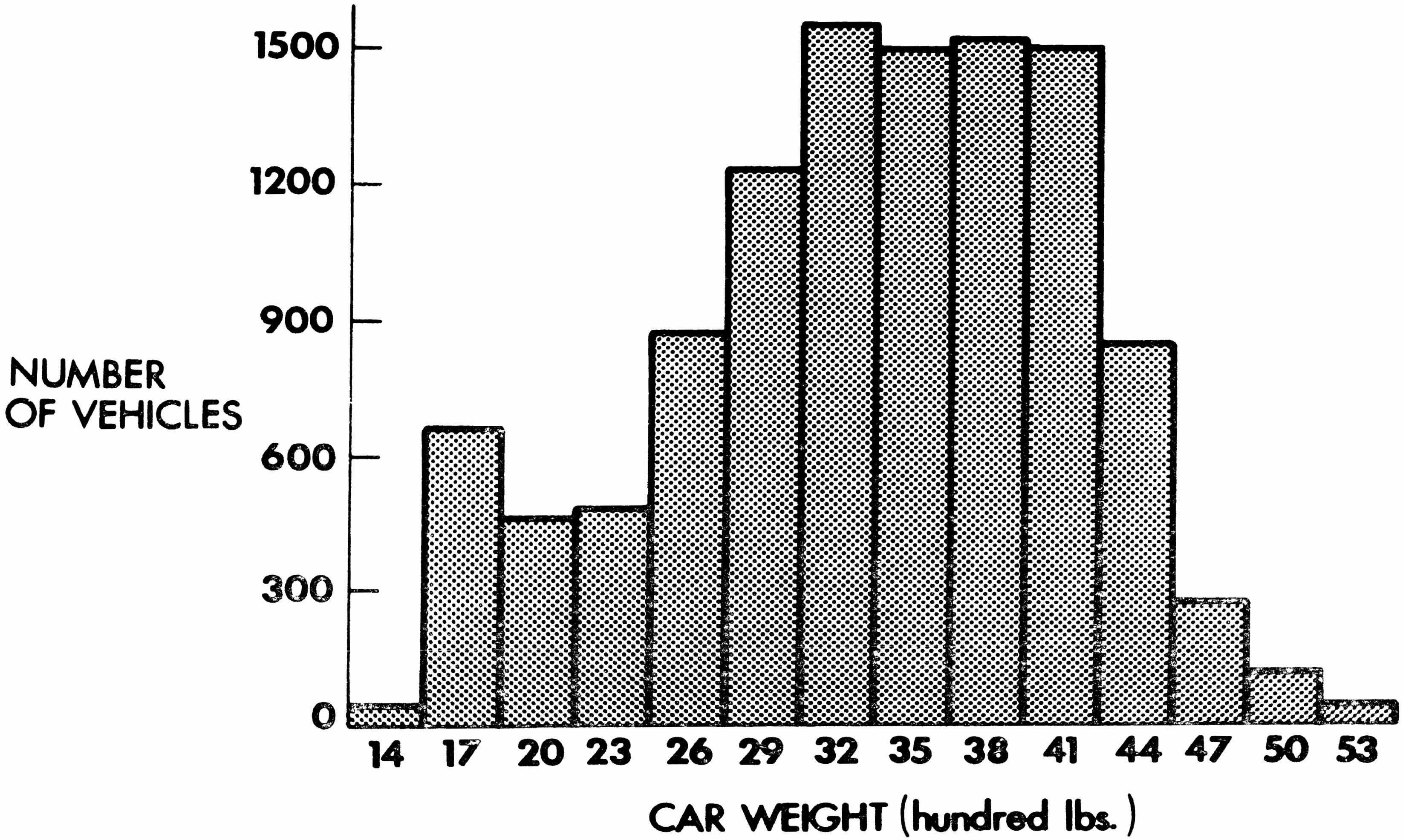
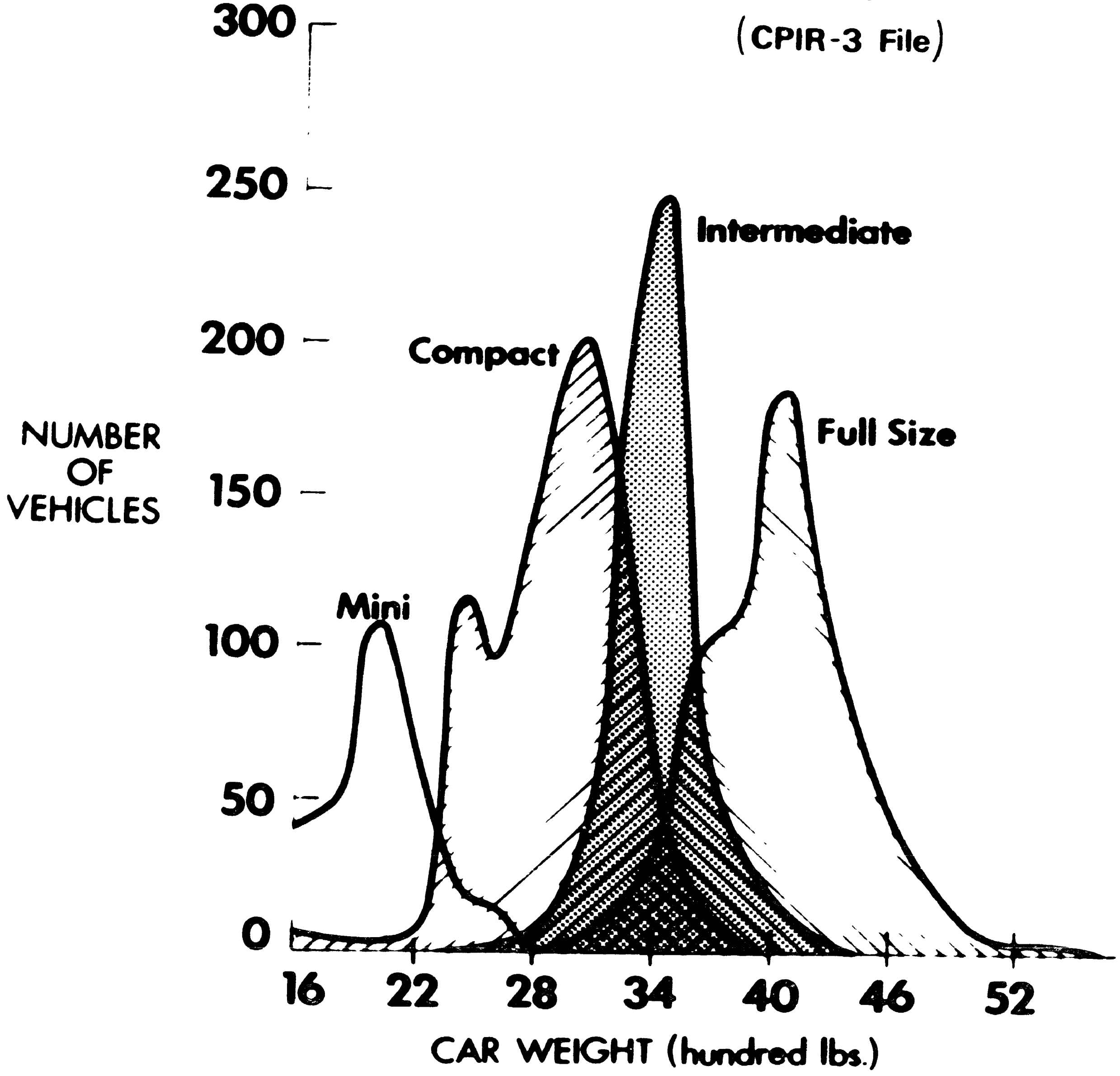


FIGURE 1

Weight Distribution By "Size" Category

(CPIR-3 File)



INJURY FREQUENCY CHARACTERISTICS

A greater number of injuries in accidents involving small cars is evident in most accident configurations. In the first column of Figure 6 the percent of involved cars is pictured in which there was at least one injury when a small car (as previously defined) collided with another small car, or, in the one case, when a small car was involved in a single vehicle collision. The second column indicates the percentage injury involvements for small cars which have interacted with a large car. The third column conversely is where large cars have interacted with a small car, and the fourth denotes large-large interactions. Head-on collisions involving small cars are most injurious, as might be expected, but they fortunately represent only about 5% of the involved population.

In Figure 7 the data are regrouped to illustrate the relative injury differences for certain collision types. In single vehicle accidents, small car occupants are more likely to incur an injury. In small-large collisions, it is clear that small car occupants sustain more injuries. This is true also for all two car collisions, though with less overall risk of injury. Restricting the data to interactions between only cars of like size, however, indicates little difference for two car collisions.

Following this idea let us hypothesize a United States with all small cars east of the Mississippi and all large cars west of it. For two-vehicle collisions, the number of accidents with

Percent Of Cars In Which There Was A Minimum Of One Injury For Different Accident Types And Car Weight Combinations

(Washtenaw County Accident File)

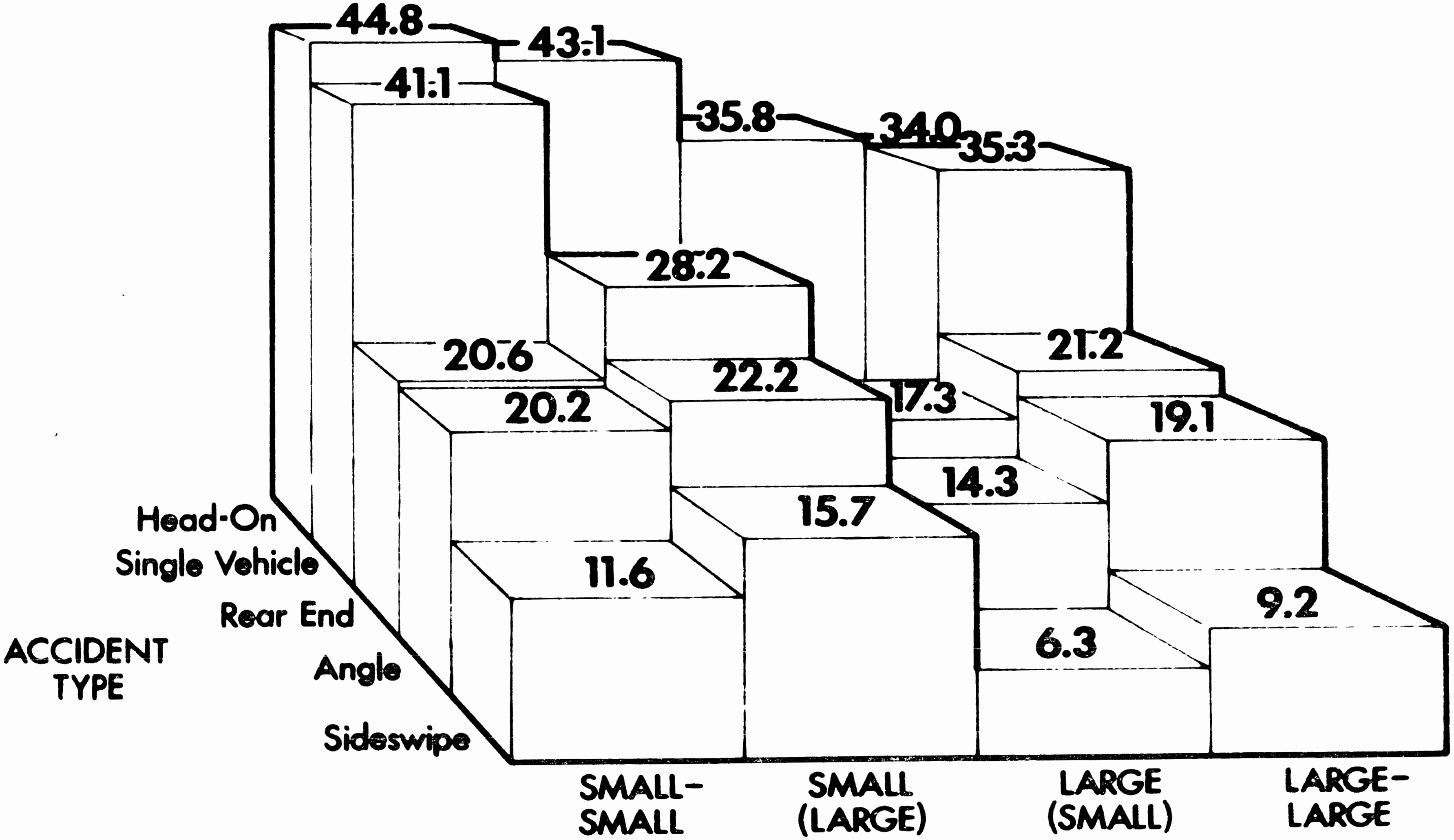


FIGURE 6

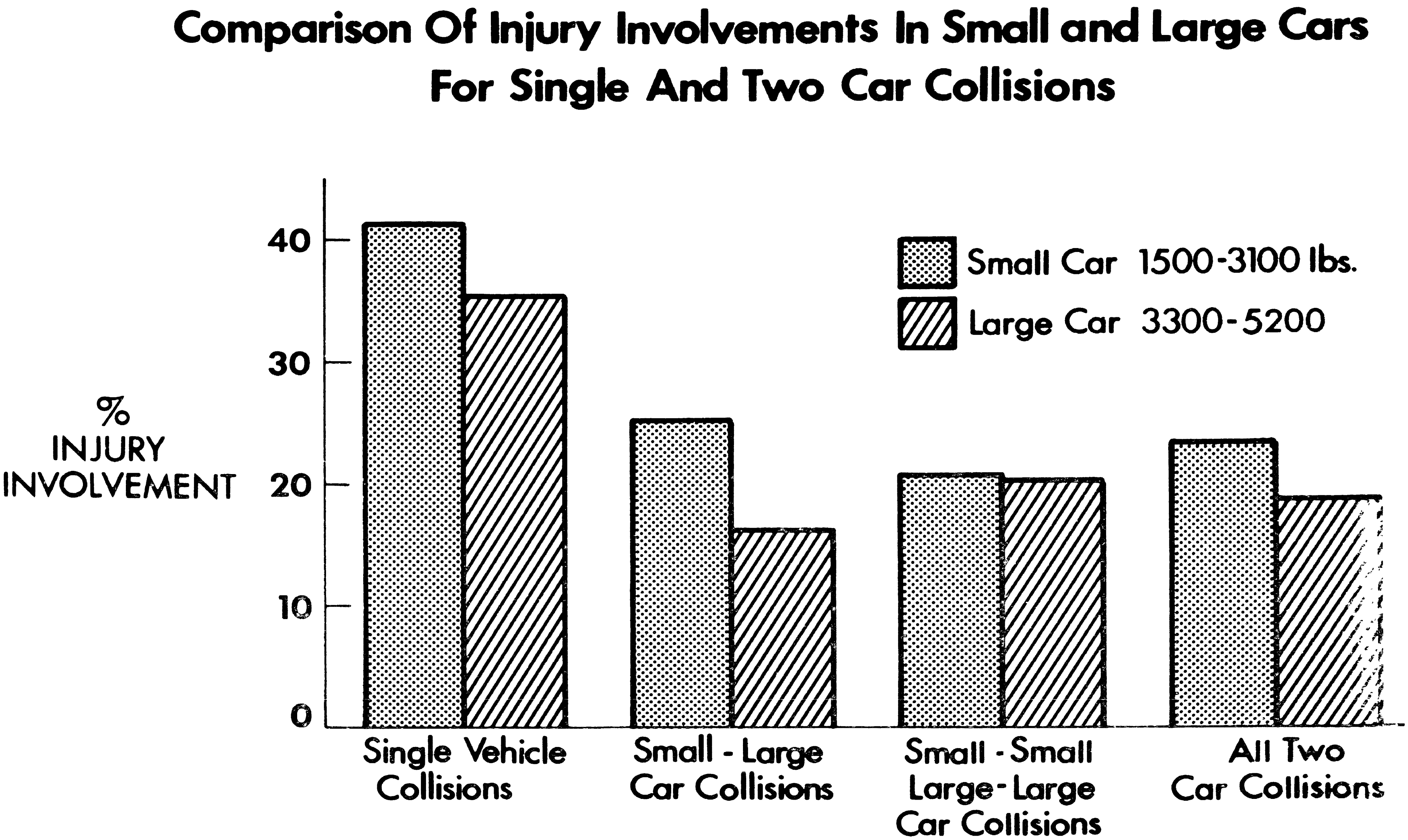

Comparison Of Injury Involvements In Small and Large Cars
For Single And Two Car Collisions
%
INJURY
INVOLVEMENT
40
30
20
10
0
Small Car 1500-3100 lbs.
Large Car 3300-5200
Single Vehicle Collisions
Small - Large Car Collisions
Small - Small Large - Large Car Collisions
All Two Car Collisions

FIGURE 7

injuries would be about the same. There would, however, be more injury accidents in the eastern half of the country as the result of single vehicle crashes. To be more specific, there would be about 50 more injury accidents per 10,000 reported accidents in the east, than in the west. The number of injuries, however, would be somewhat higher.

Figure 8 displays two curves relating injury to vehicle weight. The lower one shows the percentage of involvements with at least one injury in the studied population, and the upper curve shows the number of persons injured per hundred involvements by the weight of the involved vehicle. These curves are, of course, the result of all the kinds of accidents in which the indicated vehicle by weight was involved. Note that the number of injuries per involvement rises as the weight of the vehicle decreases, i.e., it is more likely that more than one person in the vehicle will be injured given a small car involvement. Comparing the two curves at a point designating small cars (2500 pounds) gives a ratio of 1.31, and at large cars (3750 pounds) a ratio of 1.15.

The number of injuries per accident involvement as a function of vehicle weight may be expressed in equation form from the data which generated the upper curve of Figure 8. In order to provide a good fit to the non-linear portion of the curve, an equation to the second order is given:

$$N = 10^{-8}W^2 - 1.32 \times 10^{-4}W + .642$$

where N=the number of injuries per accident involvement

W=the weight of the involved vehicle in pounds.

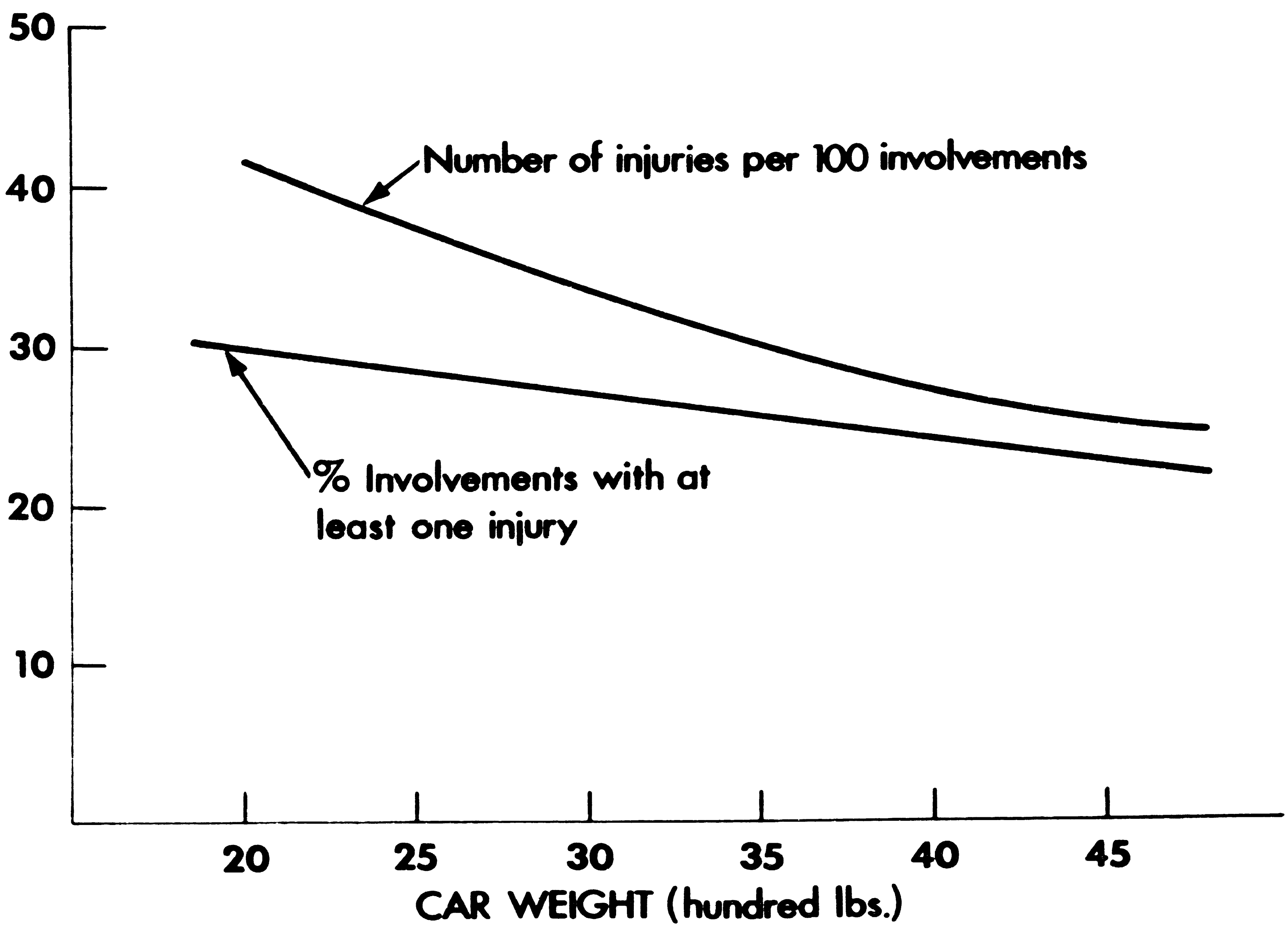

50
40
30
20
10
Number of injuries per 100 involvements
% Involvements with at
least one injury
20
25
30
35
40
45
CAR WEIGHT (hundred lbs.)

FIGURE [illegible]

RELEVANT CONSIDERATIONS

The risk of injury in a small vehicle is influenced by many other factors. In general, small cars are operated by younger drivers who may drive faster but are less prone to injury. The average age of drivers in 2000 pound cars in this population is 26 years; for 3800 pound cars 35 years. Younger drivers, at least those below 25 years of age, are involved more frequently in accidents and are more often cited for violations than their older counterparts. None of these factors, however, satisfactorily explains the increase in the number of persons injured per involvement for small cars.

Vehicle occupancy shown in Figure 9 is based on data from the CPIR-3 file, in which seat occupancy information is accurately reported. The average number of occupants in smaller cars is slightly lower than in large cars, suggesting that the increase in the number of injuries incurred in small cars is not due to more people being in these cars.

Might less use of restraints in smaller cars account for the difference? From the same source (CPIR-3 file), the percent of belted drivers (by weight of vehicle) is indicated in Figure 10. We see there is a pronounced and unexplainable dip in the center of this distribution, however, there is little difference in the use of restraints by the large and small groups defined in this study.

Mean Number Of Occupants vs Weight Of Car
(Washtenaw County / Accident File)

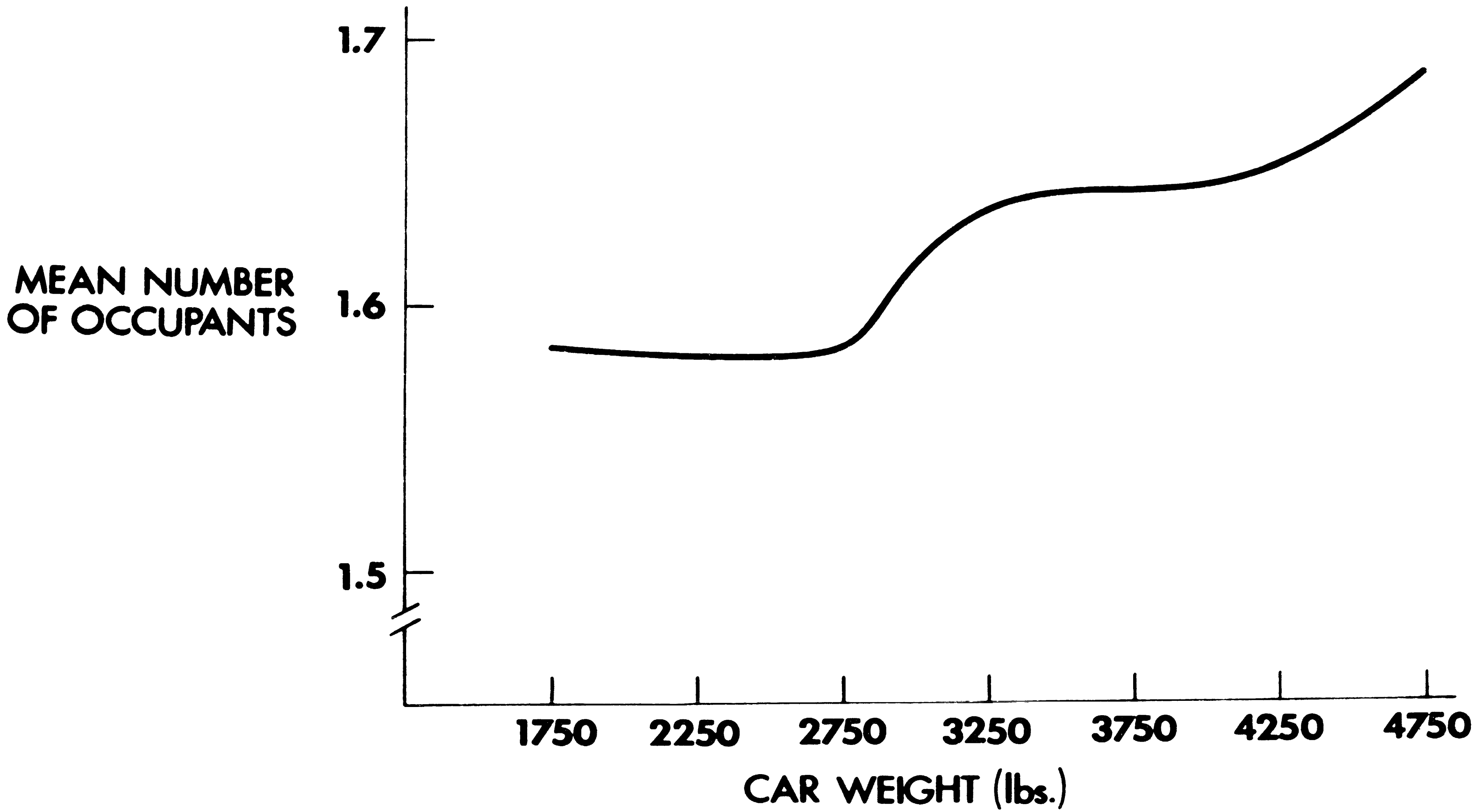


FIGURE 9

Percent Belted By Car Weight

(CPIR-3 File)

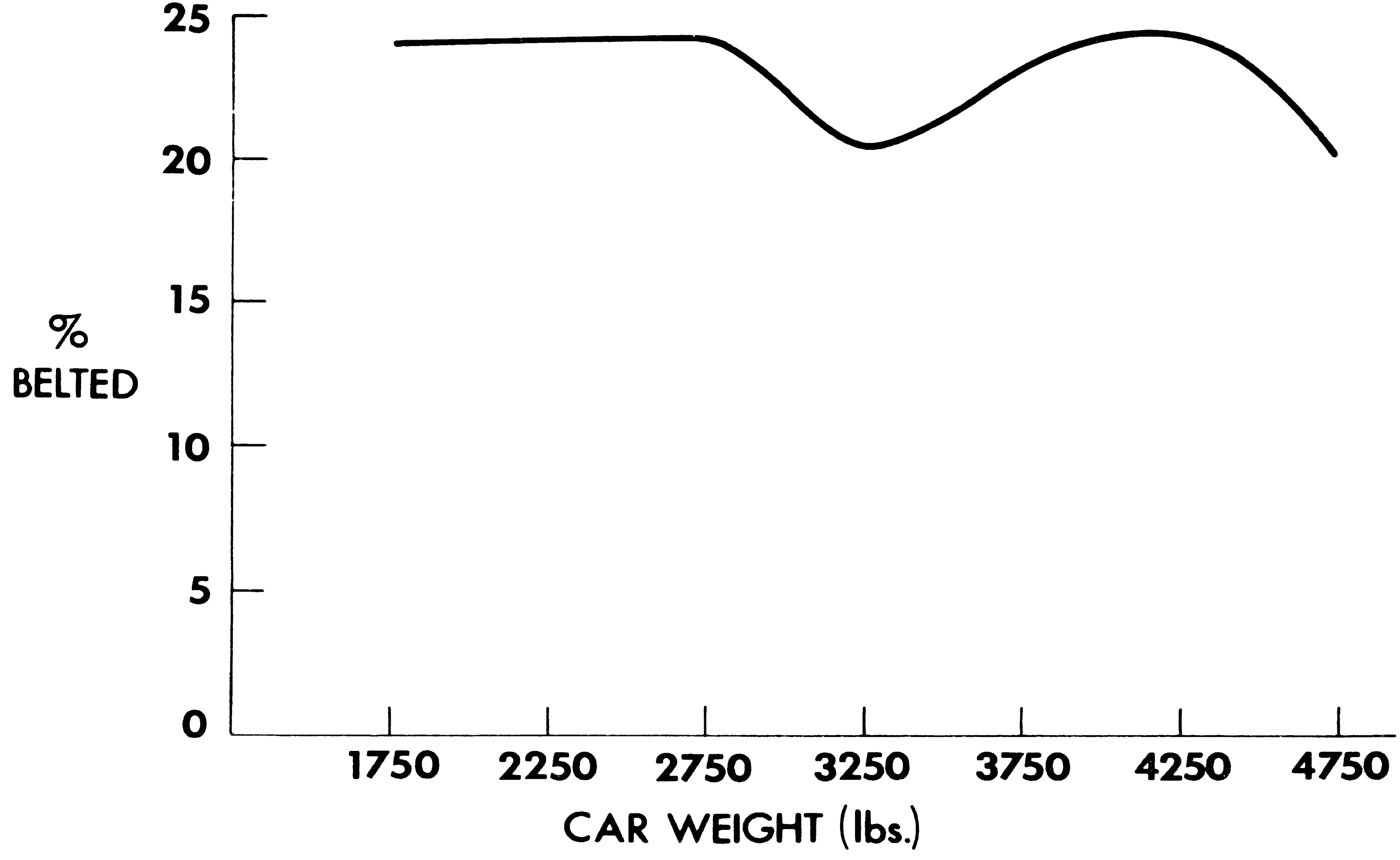


FIGURE 10

One must conclude that the increase in injuries is most probably a result of car weight and protection offered by interior size rather than from these other factors.

FINDINGS AND CONCLUSIONS

This study has attempted to describe the frequency of injury to passenger car occupants as a function of car weight and accident configuration. Data relevant to this subject has been presented in the framework of a changing distribution of weight for the passenger vehicle population.

There has been a substantial increase in lighter-weight passenger cars entering the total overall vehicle population these past three years. Generally the increase has been in the 2000 to 2500 pound range. At the same time, however, the average weight of all passenger cars has slightly increased, except for the years 1970-71 in which there was a slight decrease.

Average weight of the vehicle population at risk, as evidenced by the weights of cars involved in collisions, changes by few pounds in a single year. While there is little change in this average, it is also clear that the distribution of vehicle weight overall is changing. The void which has existed in the 2000-2500 pound range (Figure 1) is destined to disappear.

When a new car enters this population it has some chance of being involved in an accident, a chance not highly related to its weight. However, once in an accident, the chance of injury in this car increases at the rate of about 2.5% for each decrease of 100 pounds in vehicle weight.

An estimate has been presented for a situation in which all cars in the vehicle population were either small or large. In each such situation two-vehicle collisions could only occur between similar sized vehicles. However, the small vehicle population would be less safe because of increased injury occurring in single vehicle accidents. Furthermore, small cars (in the population studied here) are overrepresented in single vehicle accidents, why is not fully known, perhaps because of their drivers, or perhaps because of stability, handling or control characteristics or a combination of the two. If it is the latter, one might expect the frequency of injury to further increase even within the small vehicle population.

The change in the proportion of small cars in the vehicle population is continuing concurrently with many other changes in the traffic system. There are more cars on the road each year; all cars are becoming heavier at the same time that more small cars enter the system; the characteristics of the drivers of cars of different weights also change; at the same time many injury and accident countermeasures are being implemented. The total effect of such changes is observable in accident and injury statistics for the nation, but individual effects must be estimated by analyses such as presented here, and by theoretical extensions of what can be observed in the data.

It is clear that the individual automobile owner is safer (by 2½% per hundred pounds of vehicle weight) if he drives a larger car. It is also clear that a substantial increase in the proportion of small cars will lead to a greater number of injuries--even though the number of accidents may remain constant. It is estimated that an increase of approximately 1% in the number of injuries in 1972 over 1969 could be attributed to the change in car weight distribution occurring over that period.

The pressures toward smaller cars seem likely to continue-- cost, fuel availability, social desire, parking and handling, more second and third cars per family, are all likely to increase the proportion of small cars on the road. In a time period when there is an all out effort to reduce injuries associated with traffic crashes this would seem to be a change somewhat detrimental to overall safety. It is of interest to ask what future safety research needs might stem from this change in the vehicle population.

The increase of injuries in single vehicle crashes associated with small cars may be attributed in part to the environment. Guardrails, or impact attenuation barriers designed for a 3500 pound car sometimes provide a harsh collision for the smaller car. There are, however, some current efforts to provide for the smaller car. Some examples are the staged sand-barrel barriers described by Viner,[18] and the left side no-passing pennants at the beginning of no passing zones to compensate for the narrower vision and shorter sight distance in small cars.

Interior protection in all cars is important, but needs special attention in smaller cars if we are to reduce this greater risk of injury by $2\frac{1}{2}\%$ per hundred pounds of vehicle weight. Some people have suggested that larger cars should be designed to be more "forgiving" in collisions with small cars.[19] Certainly, occupants of smaller cars should be made to realize their safety position relative to other vehicles on the highway, and should be encouraged to wear their available restraints. If a target group most appropriate for strong arguments in favor of belts is sought, small car occupants are that group.

It is not clear from data presented here, or elsewhere, why small cars are overrepresented in single vehicle accidents. It has been suggested that small vehicles roll over more easily, and that their drivers are less able to cope with the idiosyncracies of the vehicles; alternatively many small cars are praised for their handling capability, and their drivers are noted for their youth and fast reactions, as well as perhaps taking greater risks. A fuller understanding of these phenomena would seem to be needed in consideration of performance and handling standards for small cars.

Finally, it should be noted that data presented here are not as current as we would like. That is, they include few of the modern American small cars which introduced in 1970. Data will be available in the near future for later years of accident experience. With this, the relative safety of the American 2000-2500 pound vehicle can be more accurately assessed. Hopefully, their relative safety will be better than predicted by the model presented here.

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